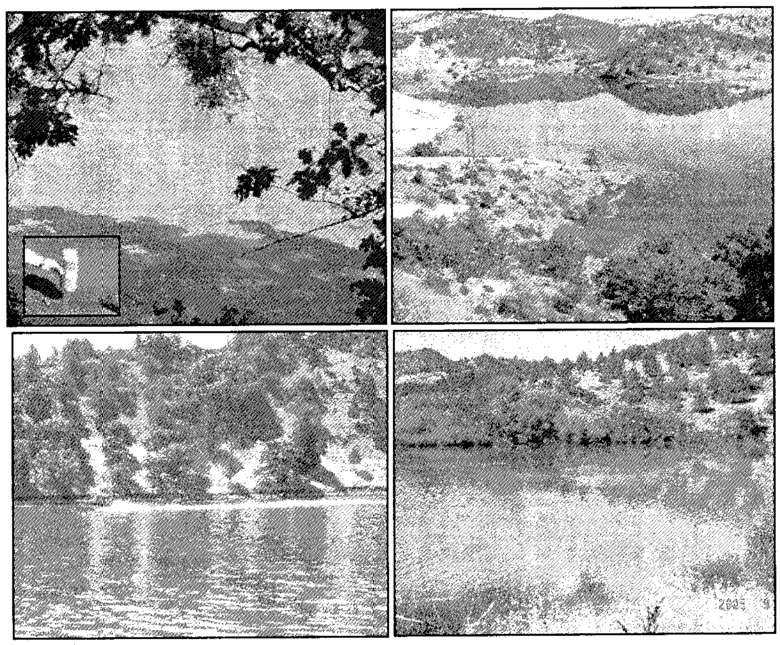
Aquatic Ecosystem Sciences LLC

TECHNICAL MEMORANDUM

Summary of 2005 Toxic *Microcystis aeruginosa* Trends in Copco and Iron Gate Reservoirs on the Klamath River, CA



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INTRODUCTION

Toxic cyanobacterial blooms are a common feature of eutrophic water bodies worldwide (Carmichael 1994). Cyanobacteria, also known as blue-green algae, are a diverse group of single-celled aquatic organisms; lakes, reservoirs, ponds, and slow-moving rivers are especially well suited to cyanobacteria, and given the right conditions – calm water, light, and abundant nutrients – these organisms can reproduce at a high rate, forming vast blooms in the water (e.g., Oliver and Ganf 2000). The resulting high cyanobacterial algal concentrations are not only aesthetically unpleasing, but often produce toxins that have been implicated in human health problems ranging from skin irritation and gastrointestinal upset, to death from liver or respiratory failure (Chorus and Bartram 1999; Chorus 2001).

Copco and Iron Gate Reservoirs (the lowermost projects of PacifiCorp's Klamath Hydropower Project-- KHP) experienced toxic blooms of the cyanobacteria *Microcystis aeruginosa* (MSAE) in 2004 and 2005 (Kann 2005). The first documented toxic bloom occurred in Copco Reservoir on September 29th 2004 when 1.9 million cells/ml of MSAE were associated with a microcystin toxin concentration of 482 µg/L (see Table 2 below). Microcystin is a potent hepatotoxin capable of causing chronic liver damage and acting as a tumor promoter (Carmichael 1995; Chorus et al. 1999; Chorus 2001).

Cell density achieved on 9-29-04 exceeded the World Health Organization (WHO) Level for Moderate Probability of Adverse Health Effects (MPAHEL; Falconer et al. 1999) by ~19 times. The microcystin toxin concentration in September, 2004 was 66 times greater than the Tolerable Daily Intake (TDI: 0.04 µg kg bw^{-1} *sensu* WHO 1998) for a 40 lb (18kg) child accidentally ingesting 100 mls of reservoir water on that date (children are more susceptible to toxins than are adults due to their smaller body size and greater potential for accidental ingestion).

In 2005 the Karuk Tribe, in cooperation with the California State Water Resources Control Board (SWRCB), began a 1-year EPA funded nutrient loading study on Copco and Iron Gate Reservoirs. Part of this study included an evaluation of seasonal phytoplankton dynamics in the river above the reservoirs, in the reservoirs, and in the river below the reservoirs. In addition, in response to the toxic MSAE bloom documented in 2004, funding was obtained for supplementary samples to document the extent and seasonal trends of surface MSAE blooms in both reservoirs.

Analysis of complete phytoplankton results for all stations, depths and dates is still in progress (Aquatic Analysts; White Salmon, WA) and a complete phytoplankton community analyses will be performed for the Karuk/SWRCB final report. However, the purpose of this report is to provide a summary of completed samples collected with respect to documentation of the extent and seasonal trends of toxic surface MSAE blooms occurring in Copco and Iron Gate Reservoirs (including stations above and below the reservoirs) between July and November, 2005.

METHODS

During the 2005 sampling season MSAE cell density, cell biovolume and microcystin toxin samples were collected from a variety of shoreline and open-water sites, including standard Karuk/SWRCB open-water locations (Table 1 and Figure 1; Stations IR01, IR03, CR01 and CR02 are open-water locations and were sampled biweekly as part of the Karuk/SWRCB nutrient loading study described above). Other stations were sampled biweekly specifically to assess the extent of toxic MSAE (Figure 1), and the stations KRAC and KRBI are Klamath River stations above Copco (KRAC) and Below Iron Gate (KRBI). Aside from IROW, which also was an open-water location, all other supplementary samples were shoreline locations. Some supplementary locations were chosen to represent conditions in the vicinity of recreational access points (e.g., CRCC, CRMC, IRCC, IRJC and IRNC) or shoreline residences (CRSS). One additional sample for microcystin toxin was collected by the Klamath Tribes at the outlet of Upper Klamath Lake (UKLOUT) on Sep 9th (Figure 1).

Table 1. Phytoplankton/microcystin sampling locations in Copco and Iron Gate Reservoirs and Klamath River stations, 2005.

STATION NAME	STATION LAT/LON	Station Description	Shoreline (SL) or Open Water (OW)
CR01	N41 58.932 W122 19.694	Copco Res. Near Dam	OW
CR02	N41 58.796 W122 17.796	Copco Res. Upper 1/2	OW
CRCC	N41 59.035 W122 19.802	Copco Res. Copco Cove Boat Ramp/Recreation Area	SL
CRJS	N41 58.705 W122 19.301	Copco Res. in Cove near Residences[1]	SL
CRMC	N41 58.441 W122 17.869	Copco Res. Mallard Cove Boat Ramp/Recreation Area	SL
CRSH	N41 58.939 W122 18.032	Copco Res. along Northern Shoreline[2]	SL
CRSS	N41 58.067 W122 16.648	Copco Res. along Southern Shoreline Near Residence	SL
IR01	N41 56.330 W122 25.930	Iron Gate Res. Near Dam	OW
IR03	N41 57.876 W122 25.389	Iron Gate Res. Upper 1/2	OW
IRCC	N41 58.368 W122 26.114	Iron Gate Res. Camp Creek Boat Ramp/Recreation Area	SL
IRJW	N41 57.721 W122 26.425	Iron Gate Res. Jay Williams Boat Ramp/Recreation Area	SL
IRNC	N41 57.810 W122 26.493	Iron Gate Res. Near Camp Creek[3]	SL
IROW	N41 56.395 W122 25.504	Iron Gate Res. Open Water Station[3]	OW
IRUS	N41 58.157 W122 23.074	Iron Gate Res. Upper Shoreline	SL
KRAC	N41 58.345 W122 12.101	Klamath River Above Copco Reservoir	River
KRAI	N41 58 22.4 W122 21 518	Klamath River Above Iron Gate Reservoir	River
KRBI	N41 55.865 W122 26.532	Klamath River Below Iron Gate Reservoir	River
UKLOUT	N 42 14.320 W121 48.282	Outlet of Upper Klamath Lake at Fremont Bridge[4]	--

[1]Sampled in September of 2004 only
[2]Initial July 2005 Sample -- not sampled regularly
[3]not sampled regularly
[4]Klamth Tribes sample for toxin only -- Sep 2005

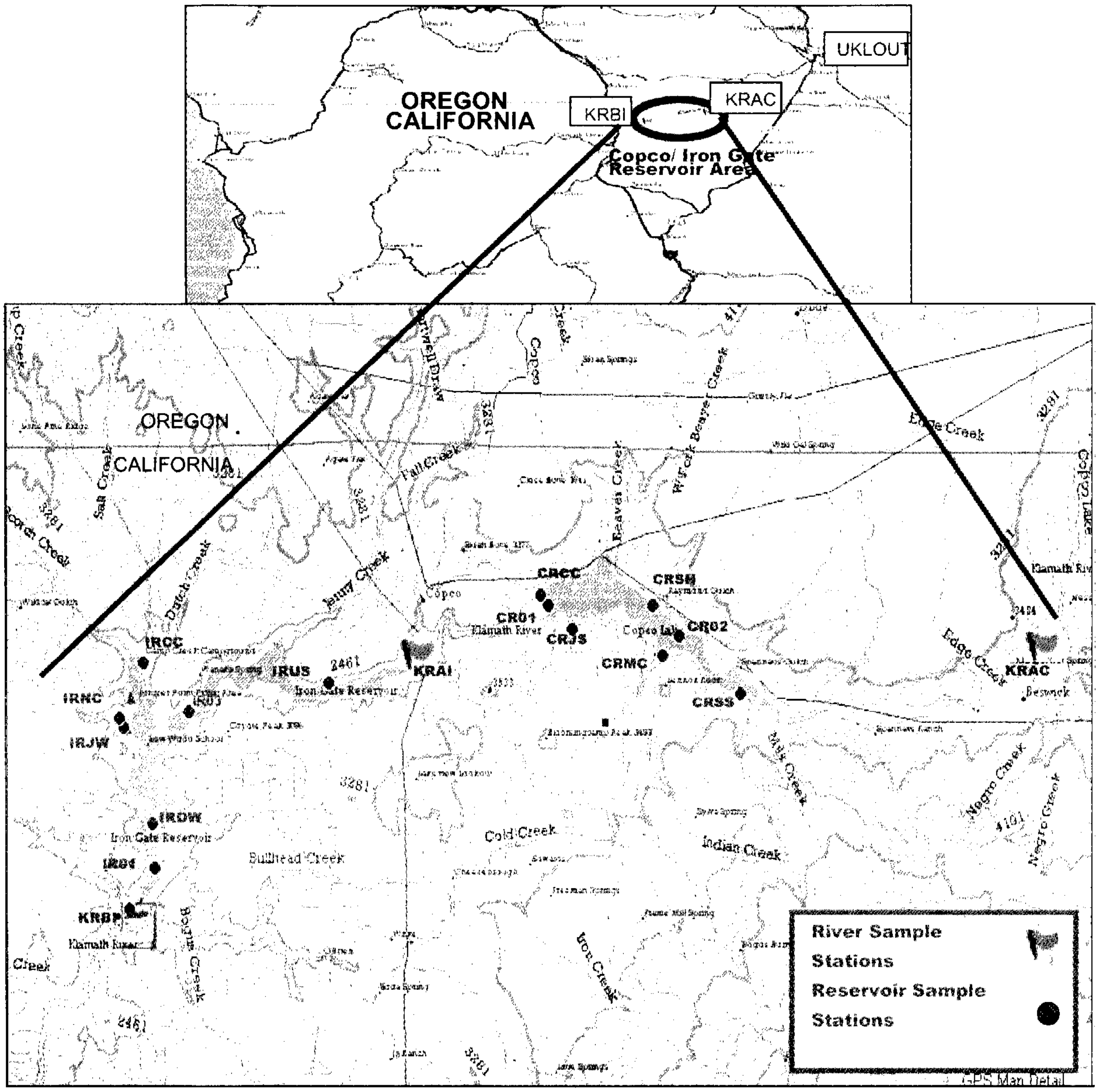


Figure 1. Location of Copco and Iron Gate Reservoir toxic cyanobacteria sampling stations, 2005.

Shoreline and open-water samples taken at the surface consisted of grab samples of surface algal material, and both open-water samples taken at 1 m and at river station KRAC were taken with a Van-Dorn water collection bottle. Samples for microscopic determination of phytoplankton density and biovolume were preserved in Lugol's Iodine and sent to Aquatic Analysts in White Salmon, WA where enumeration and biovolume measurements are determined according to APHA Standard Methods (1992). Phytoplankton laboratory reports are contained in Electronic Appendix E1.

Samples for determination of microcystin toxin were placed in a cooler with gel-ice and shipped overnight air to Wright State University in Dayton, OH (CyanoHab Services Lab of Dr. Wayne Carmichael). These samples were analyzed for microcystin toxin using ELISA methodology

(microcystin laboratory reports and methodology are contained in Electronic Appendix E2). All phytoplankton and toxin lab reports were summarized in a series of Tech Memos at the time results were received, and are available from the Karuk Department of Natural Resources. In addition, on three occasions, split samples were sent to the Oregon Department of Environmental Quality Laboratory (ODEQ) for analysis of microcystin-LR and anatoxin-a using Liquid Chromatography and Mass Spectrometer analysis (LC/MS-MS; Electronic Appendix E3) Because the ODEQ laboratory was still in method development and analyses could only be performed on the aqueous phase, the reported concentrations are not directly comparable to the CyanoHab Services Lab ELISA results. Chain of custody sheets for phytoplankton and toxin samples are on file with the Karuk Department of Natural Resources.

Quality assurance (QA) sampling was performed by splitting samples in the field using a churn splitter. One of the pair of split samples was disguised and sent with its associated split for analysis of both cell density and microcystin toxin. These results generally indicate good agreement between split samples (Figure 2a), with the majority of cell

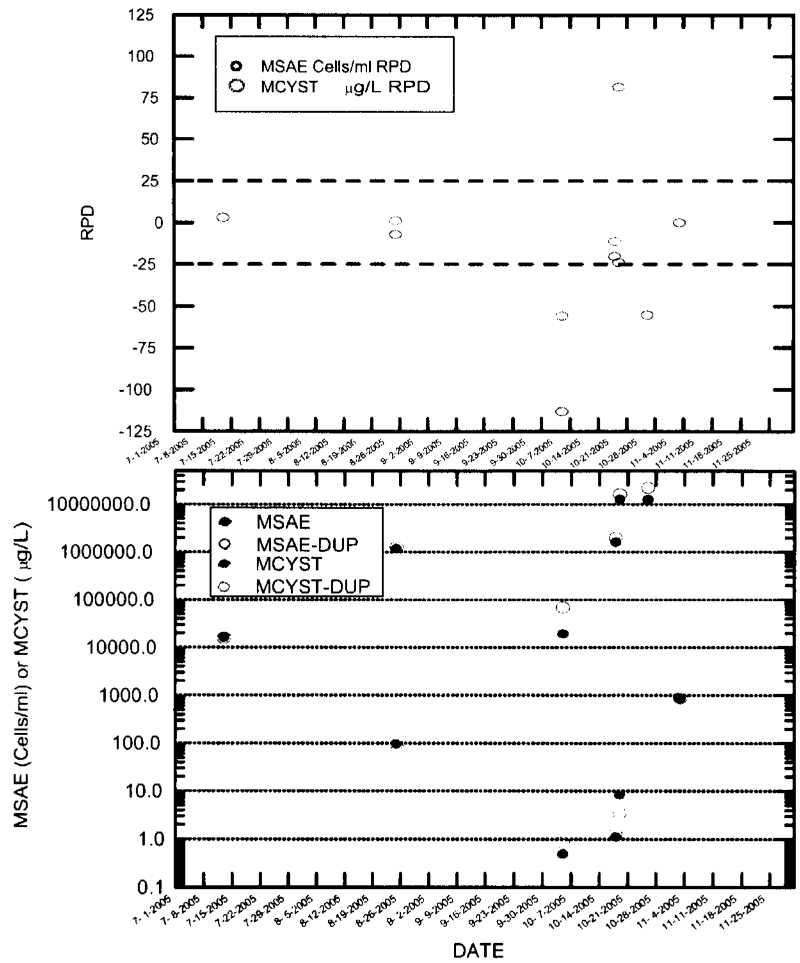


Figure 2. Analysis of field duplicate samples for MSAE cell density and microcystin concentration; relative percent difference (RPD) (a), and paired sample values (b).

density splits falling within ±25% of the relative percent difference (RPD; defined as $(((x_1-x_2)/(x_1+x_2/2))x100)$. Of the two toxin analyses falling outside the 25% RPD, the absolute values of the paired samples were low (0.87/0.49 and 8.18/3.44μg/L), with differences of 0.38 and 4.74 μg/L, respectively (Figure 2b). Although the paired samples for the two cell density values falling outside 25% RPD were both within the same order of magnitude (Figure 2b), overall resolution may be improved by increasing subsampling aliquots during microscopic analysis. Nonetheless, there were no instances when management relative to WHO guidelines would have differed based on duplicate variability.

Finally, cell density and toxin concentration were compared to MPAHEL thresholds for recreational waters as published in documents for the World Health Organization (WHO) and EPA (Falconer el al. 1999; Chorus and Cavalieri 2000). The MPAHEL is 100,000 cells/ml or 20 μg/L microcystin in the top 4 meters of surface waters, and the TDI is as described in (WHO 1998). The WHO (Falconer et al. 1999) further lists cyanobacterial scums in swimming areas as having a high probability of adverse health effects (i.e., the potential to cause acute poisoning) and recommends immediate action to prevent contact with scums.

RESULTS

The first visual detection of a cyanobacterial bloom in the reservoir system in 2005 was observed from the road along the northern shoreline of Copco Reservoir on July 13th at station CRSH (Figure 3). Subsequent analyses showed >11 million MSAE cells per ml and 667 μg/L of

Copco shoreline from road (~12 ft above water level) 7-13-05

Copco shoreline standing on shoreline 7-13-05

Copco shoreline close up 7-13-05

Figure 3. Observed bloom conditions at station CRSH on 7-13-2005.

microcystin at station CRSH (Table 2). This high cell concentration (and associated high microcystin toxin that was greater than 92x the TDI) illustrates that although cell density was low (<16,000 cells/ml) or not detected at the open water stations CR01 and CR02 on July 13th (Table 2), localized blooms (e.g., Figure 3) can still occur due to MSAE buoyancy and the concentrating effect of wind.

Table 2. *Microcystis aeruginosa* cell density, microcystin toxin concentration, and risk exceedance for toxigenic cyanobacteria in Copco and Iron Gate Reservoirs, 2005.

DATE	STATION NAME	DEPTH	*Microcystis aeruginosa* (cells/ml)	*Anabaena flos-aquae* (cells/ml)[1]	Microcystin Total (μg/L)	Exceedance of moderate risk level of 100,000 cells/ml *Microcystis* (x greater than 10^5 cells/ml)	Exceedance of moderate risk level of 20 μ/L microcystin (x greater than 20 μg/L)	Exceedance of TDI of 0.04 μg/kg/day for a 40 lb (18kg) child ingesting 100 mls (x greater than TDI)
9/29/04	CRJS	0	1,908,732	0	482.00	19	24	67
6/28/05	IR01	1	793	2,213		0		
6/28/05	IR03	1	0	541		0		
6/29/05	CR01	1	0	181		0		
6/29/05	CR02	1	0	0		0		
7/13/05	CR01	0	15,527	488		0		
7/13/05	CR01	1	0	0		0		
7/13/05	CR01-D	0	15,987	0		0		
7/13/05	CR02	1	0	0		0		
7/13/05	CRSH	0	11,402,943	38,383	667.00	114	33	92
7/14/05	IR01	1	0	0		0		
7/14/05	IR03	1	0	203		0		
7/26/05	CR01	0	0	0		0		
7/26/05	CR01	1	278	0		0		
7/26/05	CR02	1	0	145		0		
7/26/05	CRCC	0	3,316,176	0	72.16	33	3.6	10.0
7/27/05	IR01	1	0	0		0		
7/27/05	IR03	0	5,534	1,217	0.92	0	0.05	0.13
7/27/05	IR03	1	223	0		0		
7/27/05	IRUS	0	NA	NA	98.38	NA	5	14
8/10/05	KRAC	0	0	0				
8/10/05	CR01	0	151,004	0	90.35	2	4.5	12.5
8/10/05	CRCC	0	283,963	0	196.36	3	9.8	27.1
8/10/05	CRMC	0	1,427,215	0	36.58	14	1.8	5.1
8/10/05	CRSS	0	1,985,035	0	44.22	20	2.2	6.1
8/11/05	IR01	0	916,548	0	16.23	9	0.8	2.2
8/11/05	IRCC	0	1,423,430	0	14.23	14	0.7	2.0
8/11/05	IRJW	0	4,059,000	0	46.55	41	2.3	6.4
8/11/05	IRNC	0	5,350,847	0	46.02	54	2.3	6.4
8/11/05	KRBI	0	989	0		0		
8/24/05	KRAC	0	0	0		0		
8/24/05	CRCC	0	6,413,303	0	640.20	64	32.0	88.4
8/24/05	CRMC	0	9,826	0	1.40	0	0.1	0.2
8/24/05	CRSS	0	46,834,615	0	1571.70	468	78.6	217.1
8/24/05	CR01	0	28,188	0	8.00	0	0.4	1.1
8/25/05	IR01	0	528,759	0	645.40	5	32.3	89.1
8/25/05	IRCC	0	1,251,525	0	93.60	13	4.7	12.9

DATE	STATION NAME	DEPTH	*Microcystis aeruginosa* (cells/ml)	*Anabaena flos-aquae* (cells/ml)[1]	Microcystin Total (µg/L)	Exceedance of moderate risk level of 100,000 cells/ml *Microcystis* (x greater than 10^5 cells/ml)	Exceedance of moderate risk level of 20 µ/L microcystin (x greater than 20 µg/L)	Exceedance of TDI of 0.04 µg/kg/day for a 40 lb (18kg) child ingesting 100 mls (x greater than TDI)
8/25/05	IRCC-D	0	1,164,467	0	94.60	12	4.7	13.1
8/25/05	IRJW	0	17,458,065	0	632.20	175	31.6	87.3
8/25/05	IROW	0	8,944,366	0	436.90	89	21.8	60.3
8/25/05	KRBI	0	24,429	0				
9/7/05	KRAC	0	0	0		0		
9/7/05	CRCC	0	10,022,222	0	946.00	100	47.3	130.7
9/7/05	CRMC	0	737,617	0	50.00	7	2.5	6.9
9/7/05	CRSS	0	24,415,038	0	321.48	244	16.1	44.4
9/7/05	CR01	0	1,252,778	0	75.05	13	3.8	10.4
9/8/05	IR01	0	3,095,098	0	9.41	31	0.5	1.3
9/8/05	IR03	0	2,307,442	0	431.14	23	21.6	59.5
9/8/05	IRCC	0	33,407	0	10.78	0	0.5	1.5
9/8/05	IRJW	0	584,473	0	100.86	6	5.0	13.9
9/8/05	KRBI	0	42,577	0		0		
9/8/05	UKLOUT	0			0.32		0	0.0
9/20/05	KRAC	0	0	0		0		
9/20/05	CRCC	0	163,004,286	0	1994.83	1,630	99.7	275.5
9/20/05	CRMC	0	2,931,500	0	1856.54	29	92.8	256.4
9/20/05	CRSS	0	5,965,608	0	227.39	60	11.4	31.4
9/21/05	CR01	0	46,256	0	3.08	0	0.2	0.4
9/21/05	IR01	0	4,920,000	0	141.23	49	7.1	19.5
9/20/05	IRCC	0	33,995	0	2.64	0	0.1	0.4
9/20/05	IRJW	0	6,657	0	142.31	0	7.1	19.7
9/20/05	KRBI	0	8,509	0	1.27	0	0	0
10/4/05	KRAC	0	0	0	BDL[2]	0		
10/4/05	CRCC	0	28,544	0	9.29	0	0.5	1.3
10/4/05	KRAI	0			0.85		0.0	0.1
10/4/05	CR01	0	22,284,026	0	37.65	223	1.9	5.2
10/5/05	IR01	0	68,480	0	0.87	1	0.0	0.1
10/5/05	IR01-D	0	18,982	0	0.49	0	0.0	0.1
10/5/05	IRJW	0	88,617	0	5.92	1	0.3	0.8
10/5/05	KRBI	0	0	0	0.24	0	0	0
10/18/05	KRAC	0	0	0	BDL	0		
10/18/05	CRCC	0	953,620	0	3.23	10	0.2	0.4
10/18/05	CR01	0	1,986,548	0	1.25	20	0.1	0.2
10/18/05	CR01-D	0	1,621,162	0	1.12	16	0.1	0.2
10/18/05	KRAI	0			BDL			0.0
10/19/05	IR01	0	16,155,224	0	3.44	162	0.2	0.5
10/19/05	IR01-D	0	12,712,563	0	8.18	127	0.4	1.1
10/19/05	IRJW	0	980	0	BDL	0	0.0	0.0
10/19/05	IRUS	0	8,768,503	0		88		

DATE	STATION NAME	DEPTH	*Microcystis aeruginosa* (cells/ml)	*Anabaena flos-aquae* (cells/ml)[1]	Microcystin Total (μg/L)	Exceedance of moderate risk level of 100,000 cells/ml *Microcystis* (x greater than 10^5 cells/ml)	Exceedance of moderate risk level of 20 μ/L microcystin (x greater than 20 μg/L)	Exceedance of TDI of 0.04 μg/kg/day for a 40 lb (18kg) child ingesting 100 mls (x greater than TDI)
10/19/05	KRBI	0	58	0	BDL	0		0.0
10/26/05	IRUS	0	22,241,096	0	5.99	222	0.3	0.8
10/26/05	IRUS-D	0	12,596,111	0		126.0		
11/2/05	KRAC	0	0	0	BDL	0		0.0
11/2/05	CRCC	0	6,505	0	BDL	0		0.0
11/2/05	CR01	0	0	0	BDL	0		0.0
11/3/05	IR01	0	867	0	BDL	0		0.0
11/3/05	IR01-D	0	0	0		0		
11/2/05	KRBI	0	0	0	BDL	0		0.0

[1]*Anabaena flos-aquae* (ABFA) is another potentially toxigenic cyanobacteria that can produce the neurotoxin, anatoxin-a. Because cell counts were lower than the MPAHEL of 100,000 cells/ml, and anatoxin-a was not detected in ODEQ laboratory analysis (Appendix E3), ABFA is not discussed further in this report.

[2]BDL= below WSU laboratory detection limit of 0.147 μg/L

Subsequent to the July 13th sample date, toxigenic MSAE blooms continued to increase in both Copco and Iron Gate Reservoirs, with the typical bloom appearance for various dates and sample stations shown in Appendix 1. Although the blooms were widespread in both reservoirs, substantial variability was exhibited among stations and within stations on different dates (Figure 4).

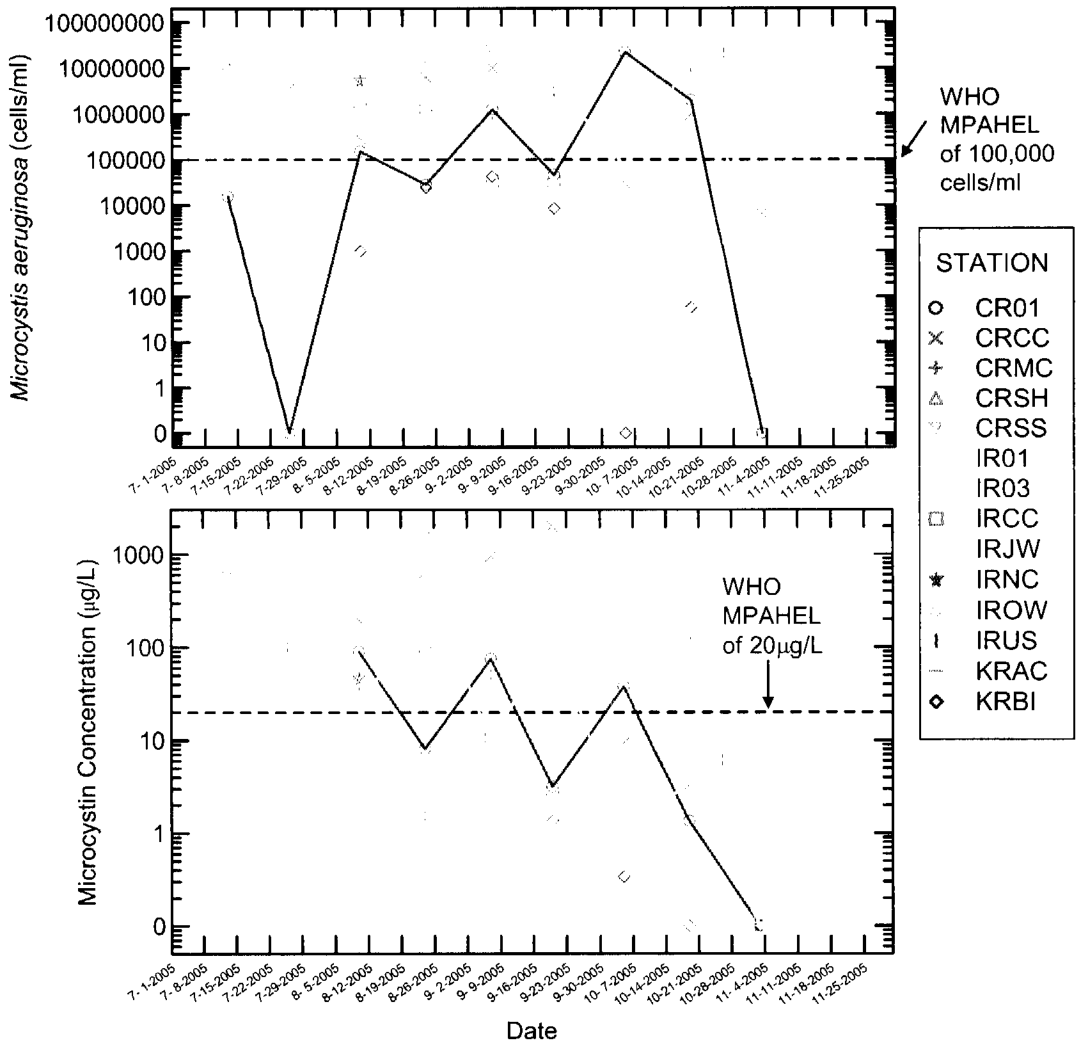


Figure 4. MSAE cell density (a) and microcystin toxin concentration (b) at all sample stations, Copco and Iron Gate Reservoirs, 2005. For reference, lines are drawn between dates for the open-water stations CR01 (red line) and IR01 (yellow line).

For example, both cell density and toxin concentration fluctuated around the WHO MPAHEL at Copco station CR01, while Iron Gate station IR01 remained substantially above the MPAHEL for cell density through early October (Figure 4). Moreover, there were numerous instances when cell density or toxin values declined below the WHO thresholds only to exceed the threshold on the following sample date. Likewise, on any given date, several of the stations were

either above or below the WHO threshold, with some shoreline stations (e.g., CRCC) showing cell density and toxin concentration levels several orders of magnitude higher than the open-water locations (Figure 4). These data illustrate spatial and temporal variability that necessitates managing for public health risk based upon multiple sampling stations and multiple dates.

A comparison of the reservoirs shows that MSAE in Copco (red boxes) may have increased earlier relative to Iron Gate (blue-green boxes), but that by early August, Iron Gate concentrations were slightly higher overall (Figure 5). All sampled reservoir stations on August 10-11 exceeded the WHO MPAHEL (Figure 5). MSAE cell density peaked in Copco in mid-September, while Iron Gate appeared to peak in mid August but then showed a subsequent increase in mid October.

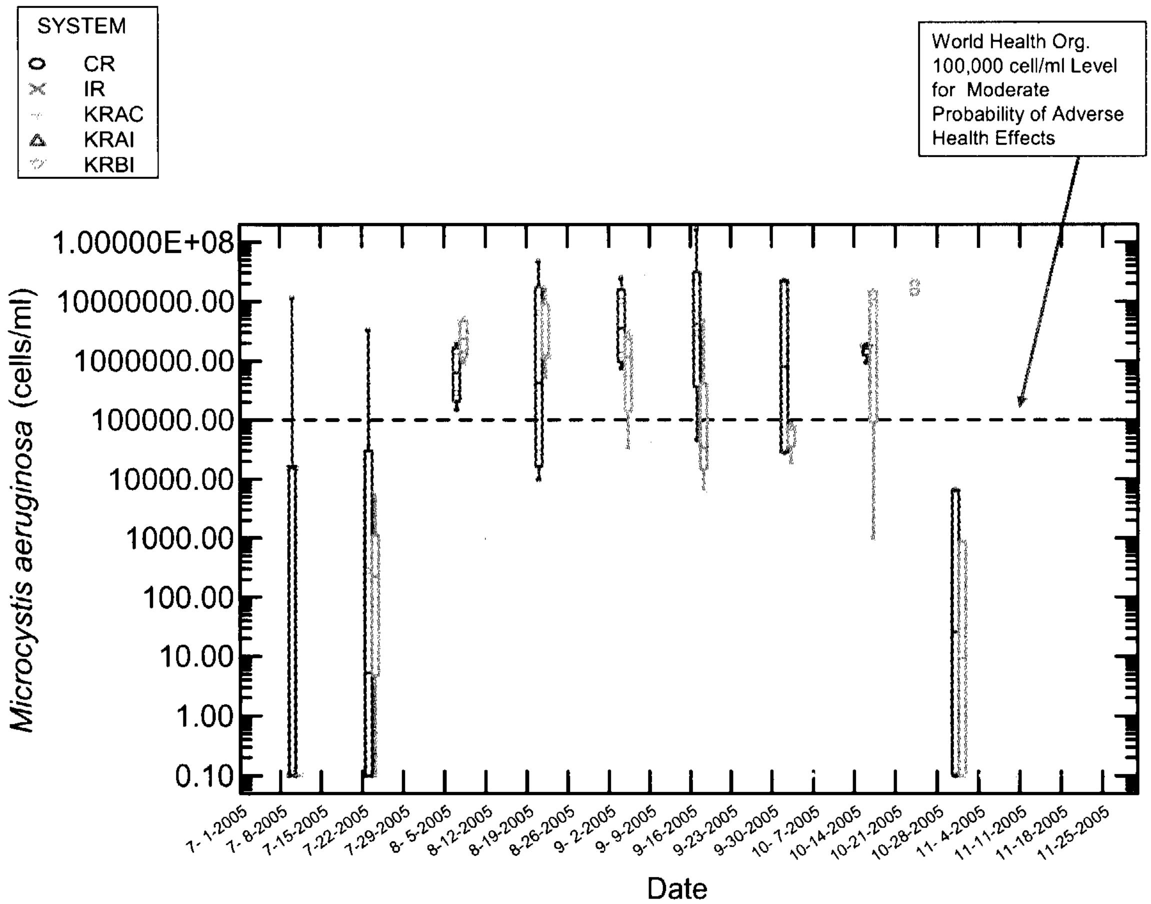


Figure 5. Box plot of MSAE cell density at Copco and Iron Gate Reservoir stations, and Klamath River stations above Copco (KRAC) and below Iron Gate (KRBI), 2005.

The blooms then abated in both reservoirs by early November. During the period of intense blooms in both Copco and Iron Gate reservoirs, the station above Copco (station KRAC; orange plus symbol in Figure 5) showed non-detects for MSAE. Conversely, the station below Iron Gate (station KRBI; green triangle in Figure 5), although lower in concentration than the reservoirs, followed a similar seasonal trajectory as the reservoir stations (Figure 5).

A summary of cell density data for both reservoirs combined shows most reservoir stations exceeding the WHO MPAHEL of 100,000 cells/ml for the majority of the Aug-Oct period (Figure 6a). During the peak cell density period of mid August to mid September, several

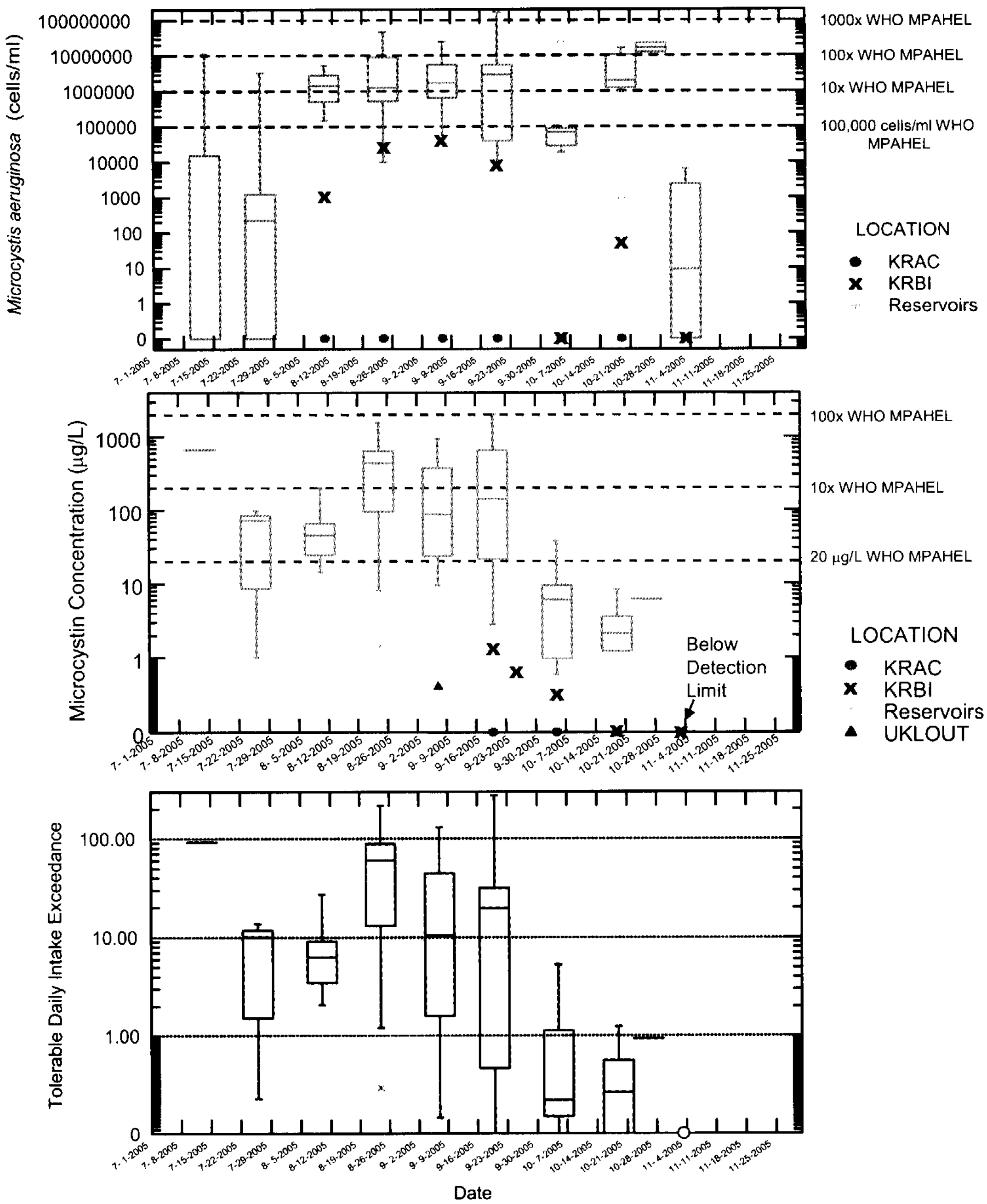


Figure 6. MSAE cell density (a), microcystin concentration (b), and tolerable daily intake (c; blue boxes=both reservoirs combined) in Copco and Iron Gate Reservoirs and Klamath River stations above Copco (KRAC) and below Iron Gate (KRBI), 2005.

stations exceeded this level by more than 100x, with a maximum cell count of 163 million MSAE cells/ml (>1000x the MPAHEL) on 9/20 (Figure 6a). As indicated above, no MSAE was detected in the Klamath River inflow to Copco on any of the measured sample dates (station KRAC; red circles, Figure 6a). Conversely, a maximum of 42,577 cells/ml of MSAE was detected in the Klamath River below Iron Gate on 9/8 (KRBI; Table 2, Figure 6a).

Microcystin toxin levels followed the general seasonal trend of cell counts, peaking in September and declining in October (Figure 6b). During the August-September period, toxin levels exceeded the MPHAEL of 20 µg/L at the majority of stations, and levels were frequently greater than 10x the MPHAEL, peaking at 1994 µg/L at CRCC on 9/20 (Table 2; Figure 6b). Median toxin values for the reservoir stations were ~50 times the MPAHEL towards the end of August (Figure 6b). Likewise, the TDI was commonly exceeded by more than 10-100x throughout the August-September period (Table 2; Figure 6c).

The toxin analysis for the sample collected at the outflow of Upper Klamath Lake (UKL) by the Klamath Tribes on 9/8 shows a low microcystin toxin level of 0.32 µg/L (Table 2; UKLOUT; blue triangle Figure 6b), and subsequent analyses show that microcystin was not detected at station KRAC (red circles; Figure 6b). Low levels of microcystin were detected at KRBI in late September and early October.

Concomitant with a decline in reservoir MSAE cell density in late October, microcystin concentrations declined to low levels or were below the detection limit (BDL), and was BDL at all stations in both reservoirs during the early November sampling period (Table 2; Figure 6b).

Although toxin concentration follows the same general seasonal trajectory as MSAE cell concentration, it is apparent that the relationship between cell density and toxin is not always consistent. For example, cell densities in October that were >1,000,000 cells/ml were associated with microcystin values that were below 10 µg/L (Figure 6a,b). Furthermore, while a scatter plot shows a generally increasing trend of toxin concentration with cell density, it is clear that wide variability exists in the relationship (Figure 7a). However, further inspection reveals that many of the low toxin values that were associated with high cell density occurred during the October sampling period (symbol labels in Figure 7a; red circles in Figure 7b). Fitting a distance weighted least squares (DWLS) smoother to these data indicates that the October only relationship has a lower trajectory than does the relationship using all months (Figure 7b).

A box plot of the ratio of microcystin per MSAE cell confirms both the variability in toxin production per unit cell density as well as seasonal differences (Figure 8). For example, the interquartile range in the ratio is greater than 6 times (e.g., for August), and the overall distribution of the ratio during October is clearly lower than that for July-September (Figure 8).

Because toxin production is variable per unit cell density, simply applying a mean or median ratio to predict toxin from cell count could greatly under or over predict the actual concentration (Table 3). For example in August, estimation of toxin per 100,000 cells (the WHO MPAHEL) is 2.23 µg/L using the lower quartile ratio value, and is 14.25 using the upper quartile value (Table 3). Moreover, using the maximum ratio value produces an estimated microcystin concentration of 100 µg/L.

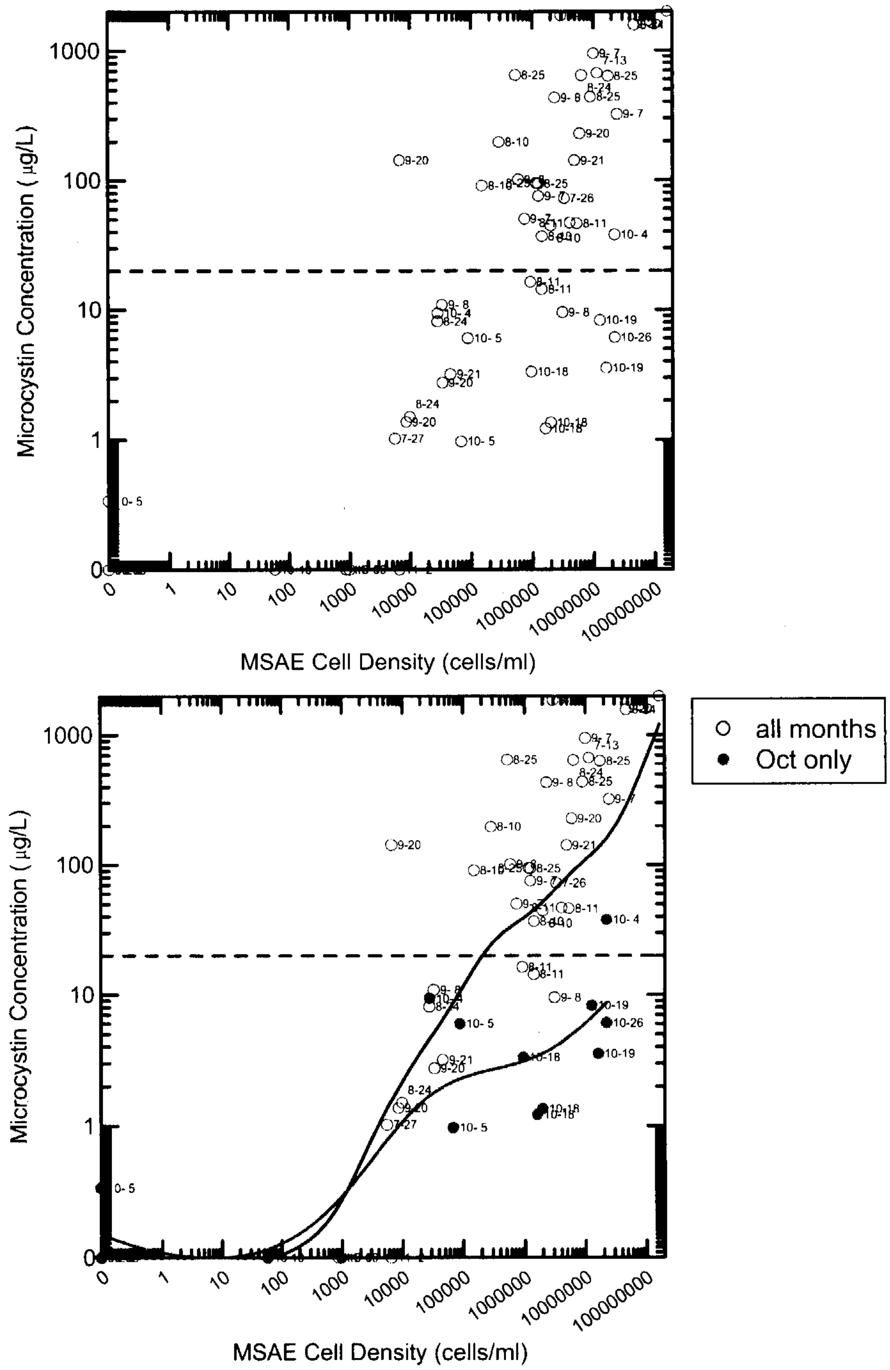


Figure 7. Relationship between MSAE cell density and Microcystin toxin concentration (a; symbol labels are sample dates), and (b) same data with distance weighted least squares (DWLS) smoother applied to all data (blue) and October data only (red) in Copco and Iron Gate Reservoirs, 2005.

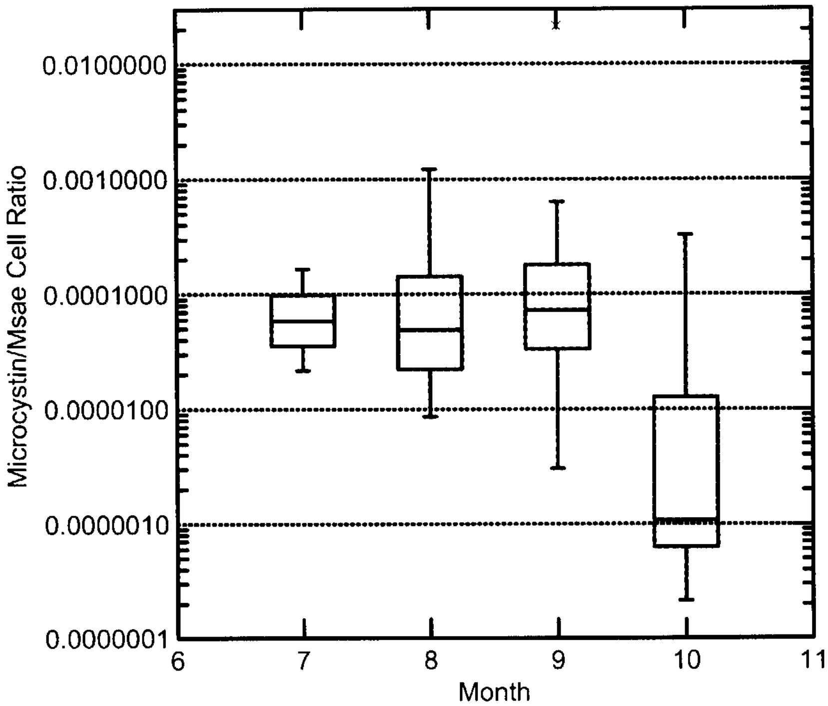


Figure 8. Box plot of the ratio of microcystin toxin per unit MSAE cell density for Copco and Iron Gate Reservoirs, 2005. Lower hinge of the box is the lower quartile (25th percentile), upper hinge is the upper quartile (75th percentile), and the whiskers are values 1.5x the upper or lower quartile.

Table 3. Estimation of microcystin per 100,000 MSAE cells using the lower quartile, median, upper quartile, and maximum ratio values, Copco and Iron Gate Reservoirs, July- October, 2005.

							Estimated Microcystin per 100,000 cells/ml			
Month	n	Minimum	Lower Quartile (25th percentile)	Median	Upper Quartile (75th percentile)	Maximum	Comput ed using Lower Quartile (mg/L)	Computed using Median (mg/L)	Computed using Upper Quartile (mg/L)	Computed using Maximum (mg/L)
July	3	2.18E-05	4.01E-05	5.85E-05	1.12E-04	1.66E-04	4.01	5.85	11.24	16.62
August	17	8.60E-06	2.23E-05	4.88E-05	1.42E-04	0.001	2.23	4.88	14.25	100.00
September	16	3.04E-06	3.34E-05	7.27E-05	1.80E-04	0.021	3.34	7.27	17.97	2100.00
October	12	0	2.41E-07	6.66E-07	8.04E-06	3.25E-04	0.02	0.07	0.80	32.55

Given the variability in toxin production per unit MSAE cell density, an alternative nonparametric cross-tabulation probability approach outlined by Kann and Smith (1999) is useful for determining risk from a public heath standpoint. Methodology for this approach is described in Kann and Smith (1999) and involves computation of exceedance probabilities for a chosen threshold value (in this case 10 or 20 µg/L microcystin) within ordered groups of an independent variable (in this case MSAE cell density). Here, the probability (frequency) of exceeding either 10 or 20 µg/L was then plotted against the median value for MSAE cell density for each ordered group (Figure 9).

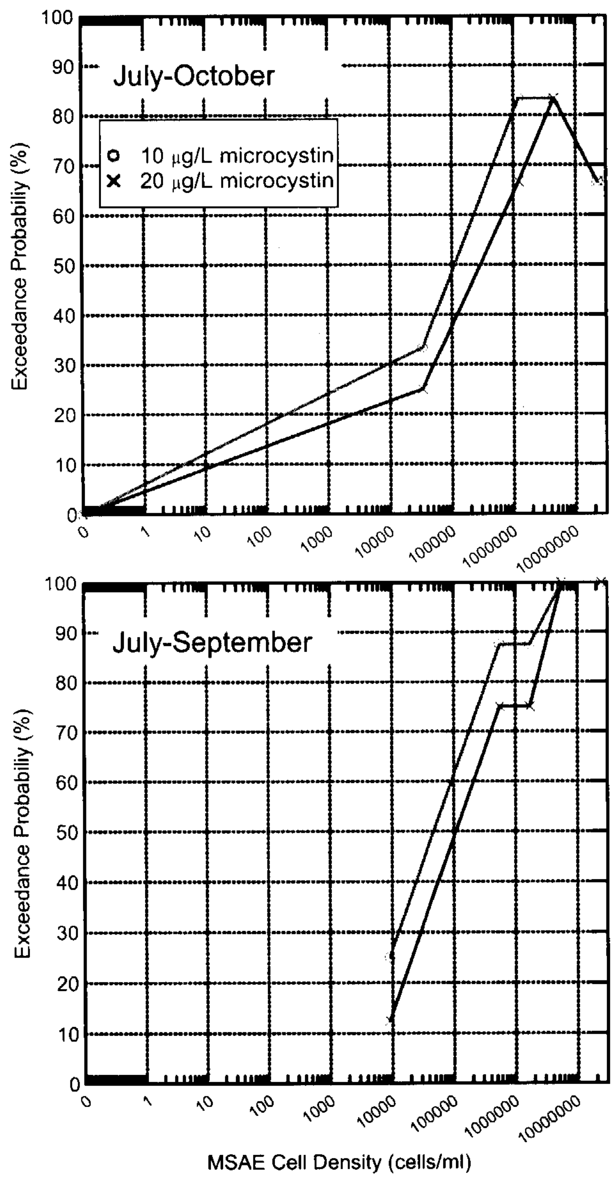


Figure 9. Probability of exceeding two critical microcystin toxin levels at varying MSAE cell density for July-October (a) and July-September (b) in Copco and Iron Gate Reservoirs, 2005. Exceedance probability is computed using nonparametric cross-tabulation method described in Kann and Smith (1999).

These data show that the July-October nonparametric model predicts that at 100,000 cells/ml MSAE the probability of exceeding 10 and 20 µg/L microcystin is ~48% and ~37%, respectively (Figure 9a). At 1,000,000 cells/ml MSAE these probabilities increase to 80% and 65% respectively. Confirming the October decline in per unit toxin production (e.g., Figure 8 above), the July-September model predicts greater frequency of exceedance (i.e., 60% and 49% for 10 and 20 µg/L at 100,000 cells/ml; Figure 9b) than is predicted from the model using all months (48% and 37% at 100,000 cells/ml; Figure 9a). It should also be noted that consistent with the new Australian guideline of 50,000 cells/ml MSAE and 10µg/L microcystin (NHMRC 2005), the July-September model shows that 10 and 20 µg/L showed an exceedance probability of 50% and 39% at 50,000 cells/ml. In other words, at 50,000 cells/ml MSAE, 10 µg/L microcystin was met or exceeded 50% of the time in Copco and Iron Gate Reservoirs.

DISCUSSION

The results of the 2005 sampling program demonstrate widespread and high abundance of toxigenic MSAE blooms in Copco and Iron Gate reservoirs from July-October. MSAE cell density exceeded the WHO MPHAEL of 100,000 cells/ml by 10 to over 1000 times during these months (Figure 6). Likewise, microcystin toxin concentration exceeded the 20 µg/L MPAHEL by 10 to over 100 times, and a 40 pound child accidentally ingesting 100 milliliters of reservoir water would have exceeded the WHO tolerable daily intake level by 10 to over 100 times.

Consistent with the patchiness expected for a buoyant species such as MSAE (e.g., Reynolds 1986), MSAE cell density in Copco and Iron Gate reservoirs was variable both spatially and temporally (Figure 5). Such spatial and temporal variability necessitates managing for public health risk based upon multiple sampling stations and multiple dates.

For the sampled dates both cell density and toxin data indicate that neither toxin nor MSAE cells were detectable in the Klamath River directly above the reservoirs in 2005. During the same sample dates when in-reservoir data (the boxes in Figures 6a,b) showed substantial MSAE cell density and toxin concentration, the station KRAC showed non-detects for both parameters (red circles in Figures 6a and 6b). Although periodic concentrations of MSAE are known to occur in Upper Klamath Lake (e.g., see Kann 2006), less than 1µg/L of microcystin was detected at UKLOUT on 9/9 (Figure 6b). On this same date Copco and Iron Gate reservoir stations exhibited substantial microcystin concentrations that were 100's of times higher than the concentration at the outlet of Upper Klamath Lake (Figure 6b).

As outlined in Kann (2006), these data are consistent with literature showing that MSAE and other buoyant cyanobacteria do not dominate in conditions of turbulent mixing such as that known to occur in the Klamath River above Copco and Iron Gate Reservoirs. For example, Huisman et al. (2004) demonstrate that potentially toxic MSAE dominate at low turbulent diffusivity (calm-stable conditions) when their flotation velocity exceeds the rate of turbulent mixing. Such conditions are more likely to occur in lakes and reservoirs as velocity and turbulence are reduced. The non-detects at KRAC (above Copco reservoir) even when reservoir

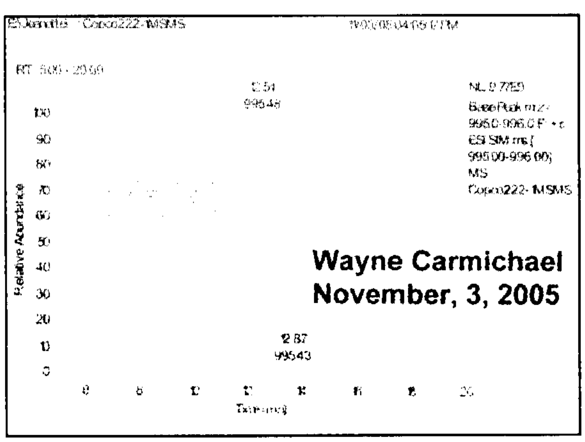
stations showed substantial concentrations of both toxin and MSAE cell density, clearly indicate the role of the reservoirs in providing ideal habitat conditions for MSAE.

Moreover, as indicated by cell count and toxin data at KRBI (below Iron Gate Dam), the potential exists for export of both cells and toxin to downstream environments. In areas where turbulent diffusivity may decrease as the river widens or such as would occur in backwater areas, the potential exists for high concentrations to occur downstream. In fact, MSAE cells and toxin were detected as far down river as the Klamath River estuary (Fetcho 2006; Kann 2006).

Toxin production per unit cell density was highly variable both within a month and between months (Figures 7 and 8). However, the probability of exceeding critical microcystin toxin values increases as MSAE cell density increases (Figure 9a,b). Public health guidelines can incorporate seasonal variability as well as alternative guideline values using the nonparametric approach shown in Figure 9.

Although the WHO MPAHEL is 20 µg/L, newly derived Australian guidelines for toxic cyanobacteria recommend 10 µg/L as a level when local authorities and health authorities should warn the public that the water body is considered to be unsuitable for primary contact recreation (NHMRC 2005). It is clear that cell density values lower than the WHO MPAHEL of 100,000 cells/ml were associated with increased probability of exceeding critical levels. For example, consistent with the new Australian guideline of 50,000 cells/ml MSAE, the July-September model shows that microcystin values of 10 and 20 µg/L exhibited exceedance probabilities of 50% and 39% at 50,000 MSAE cells/ml (Figure 9).

The derivation for WHO and Australian guidelines is based on the microcystin variant microcystin-LR, and the ELISA tests performed on Copco and Iron Gate samples do not distinguish among microcystin variants (variants such as -LR, -LA, -LL, -LW, -RR vary in toxicity; some more and some less toxic than –LR) . However, ODEQ LC/MS tests performed on the aqueous portion showed that substantial amounts of microcystin-LR existed in samples from this study (Appendix E3). In addition, LC/MS testing on Copco station CRCC from 9-20-05 (MSAE density >163 million cell/ml; ELISA microcystin 1994 µg/L) showed the relative abundance of the -LR variant to be near 100% (written communication, Wayne Carmichael, November 3, 2005Wright State University—shown below).



Given existing guidelines, MSAE bloom conditions in Copco and Iron Gate Reservoirs in 2005 represented a clear public health risk with respect to water contact recreation. Similar to the new Australian guideline of 50,000 cells/ml MSAE, at which point a water body is considered to be unsuitable for primary contact recreation, WHO guidelines consider a cyanobacterial scum in a bathing (swimming) area to be cause for a high probability of adverse health effects. At that point they recommend "immediate action to control scum contact" (WHO 2003). Copco and Iron Gate reservoirs experienced both high MSAE cell density (10 to100's of times higher than guideline levels) and the presence of scums in shoreline and open-water recreation areas in 2005.

Despite such high densities of MSAE in Copco and Iron Gate Reservoirs, to our knowledge there have not been reported illnesses or animal deaths. However, there are several reasons why this may be the case: 1) illnesses are likely to be underreported, especially if reservoir users are not aware of the potential symptoms and linkage with exposure to toxic blooms, 2) there can be a substantial lag time to the onset of symptoms. For example, according to WHO (2003), subacute liver injury is likely to go unnoticed for two reasons:

1. liver injury results in externally noticeable symptoms only when it is severe;
2. acute dose–response curves for microcystins are steep.

Therefore, according to WHO (2003):

> "little acute damage may occur until levels close to severe acute toxicity are reached. As a result of the lack of apparent symptoms at moderate exposure, exposure is likely to be continued by people uninformed of the risk (e.g., for consecutive days of a holiday or a hot spell), which will increase the risk of cumulative liver damage."

Absent state-wide toxic cyanobacterial management guidelines for California in 2005, state and local health authorities utilized existing guidelines from the World Health Organization to issue a series of health advisories and press releases (Appendix 2 showing timeline of MSAE events). Continued work on developing a standard state-wide protocol for issuing advisories and alerting the public is essential for protecting public health. Further monitoring of Copco and Iron Gate Reservoirs to protect public health and understand bloom dynamics is recommended.

Disclaimer

Due to the patchy nature of blue-green algal blooms it is possible for higher Microcystis aeruginosa densities (and therefore higher microcystin toxin concentrations) to have been present in locations not covered in this survey, particularly along shorelines or protected coves and backwaters during calm conditions of little to no wind. Recreational users should always avoid contact with water whenever noticeable surface concentrations of algae are evident. Moreover, because pets or other domestic animals are the most likely to ingest contaminated water, these animals should not be allowed access to areas of either noticeable surface concentrations of algae or when an obvious green to blue-green appearance is evident.

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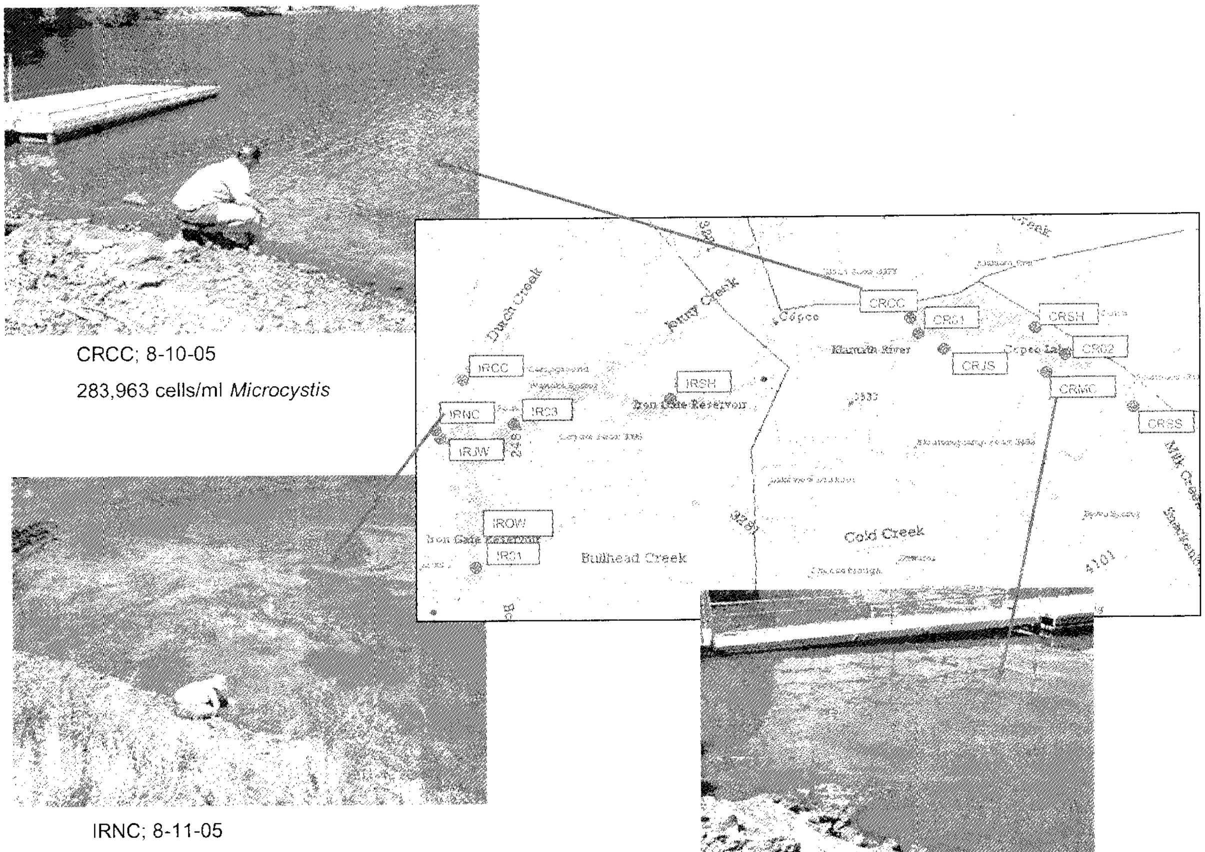
APPENDIX 1
Typical bloom appearance for various dates and sample stations

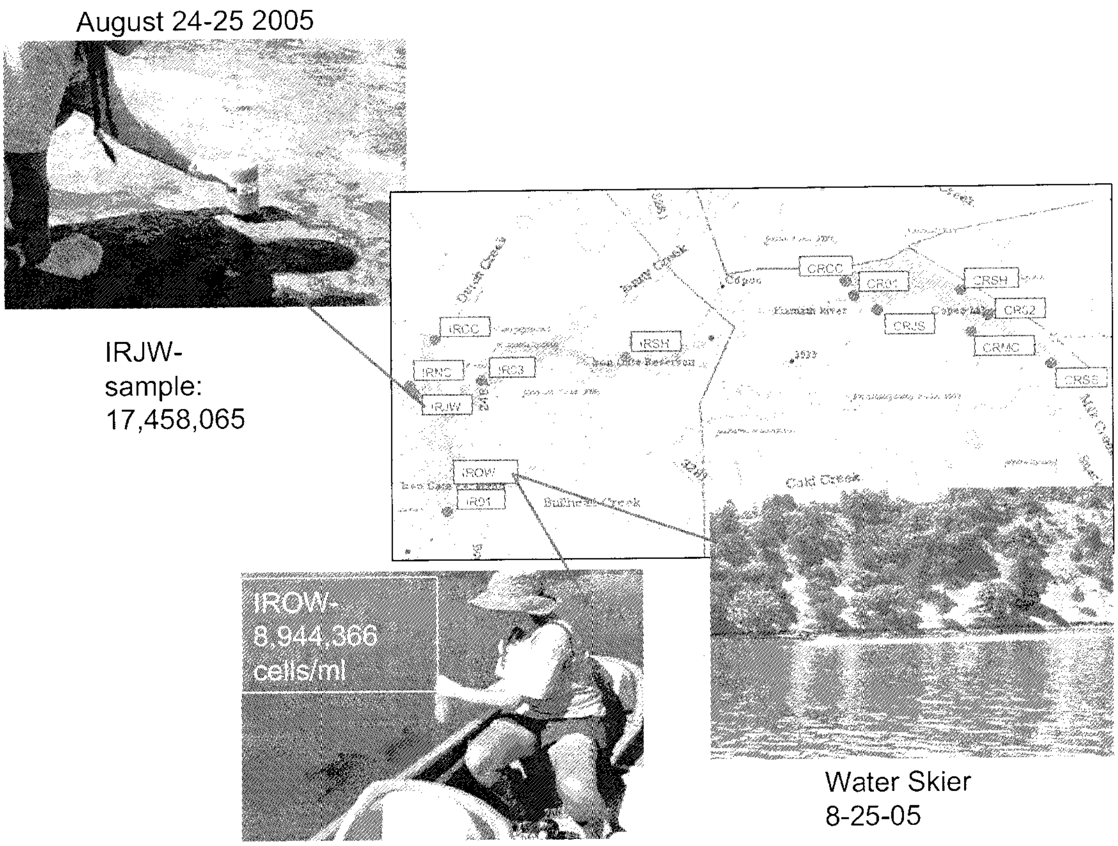


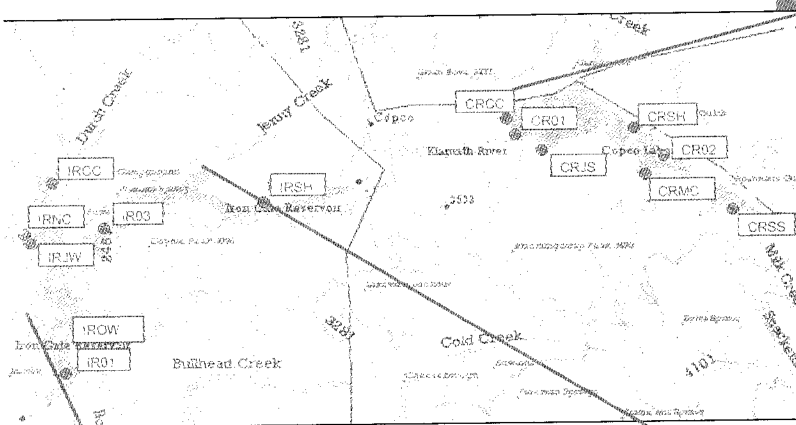
CRCC; 8-10-05
283,963 cells/ml *Microcystis*

IRNC; 8-11-05
5,350,847 cells/ml *Microcystis*

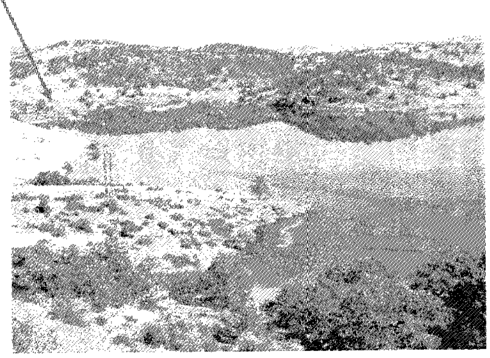
CRMC; 8-10-05
1,427,215 cells/ml *Microcystis*

EPA1136

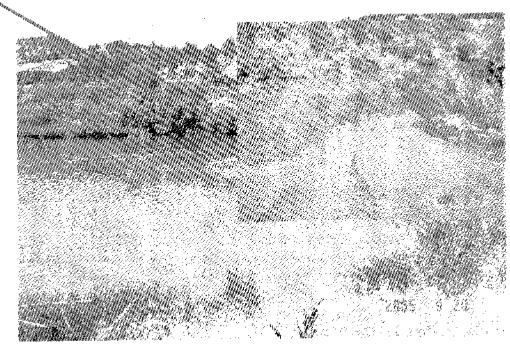

August 24-25 2005
IRJW-
sample:
17,458,065
IRCC
IRNC
IRJW
IRC3
IRSH
IROW
IR01
CRCC
CR01
CRJS
CRSH
CR02
CRMC
CRSS
Copco
Klamath River
Jenny Creek
Bullhead Creek
Cold Creek
IROW-
8,944,366
cells/ml
Water Skier
8-25-05



CRCC
Shoreline, (>163 million cell/ml)
09-20-05



IR View,
09-20-05



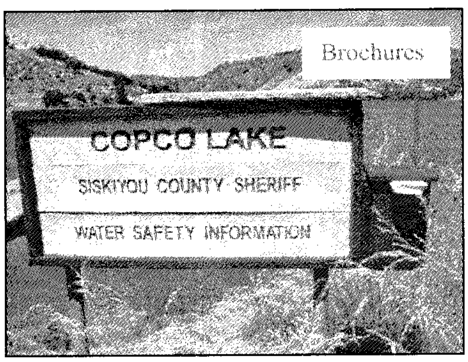
IR Jenny Creek
Cove, 09-20-05.

APPENDIX 2
Timeline of Toxic MSAE Events in Copco and Iron Gate Reservoirs, 2005

- 6/28 MSAE found in Iron Gate Reservoir in open water station at 1 m depth. Sample had 793 cells/ml MSAE.

- 7/13 MSAE found in Copco Reservoir on northern shoreline. Sample had 11.4 million cells/ml MSAE and 667 µg/L microcystin. This exceeded WHO moderate risk level by 114 and 33 times, respectively.

- 8/10 Brochures were noted ~28 days later in existing closed boxes or were posted on the back of existing signs at some public recreation areas



- 8/23 Karuk Tribe issued press release "Klamath Reservoirs Plagued by Toxic Algae *Algal Toxins Pose Significant Health Risk to Community*".

Karuk Tribe of California

P R E S S R E L E A S E

<u>For Immediate Release</u>: August 23, 2005

<u>For more information:</u>

Craig Tucker, Spokesperson *Karuk and Yurok Tribes* 530-627-3446 x27

Klamath Reservoirs Plagued by Toxic Algae
Algal Toxins Pose Significant Health Risk to Community

Happy Camp, CA – A recent analysis of water samples from Copco and Iron Gate Reservoirs reveal high levels of the toxic blue-green algae *Microcystis aeruginosa* which produces a compound known to cause liver failure. Samples taken from areas frequented by recreational users of the reservoir contained cell counts 100 times greater than what the World Health Organization (WHO) considers a moderate health risk. The observation of blue-green scum on the water's surface by water quality specialists indicate that toxin levels fall into the WHO's high risk category. The 'scum' is actually mats of the algae referred to as blooms.

The reservoirs are located on the Klamath River near the Oregon border between Ashland, OR and Yreka, CA.

According to Karuk Tribe Water Quality Coordinator Susan Corum, "We collected samples from sites near the shore frequented by recreational users. We observed thick mats of blue-green scum at the collection sites, indicating that there could be a serious problem with microcystin contamination."

The WHO reports that animal poisonings and human illnesses related to the blue-green algae *Microcystis aeruginosa* are usually accompanied by the presence of scum material at the water surface, and that ongoing observation of beaches is necessary to assess the existence of high-risk exposures.

WHO reports indicate that exposure to high levels of microcystin can produce symptoms such as eye and skin irritation, vomiting and stomach cramps, diarrhea, fever, headache, pains in muscles and joints, and weakness. However, chronic long term exposure can be more dangerous as symptoms may not develop until much damage has been done.

There are two aspects of chronic microcystin damage to the liver—progressive active liver injury and the potential for promotion of tumor growth. Tumor formation has been induced in laboratory studies in mice. Thus liver failure or cancer could result if someone is exposed often over the course of years.

Earlier this year in Humboldt County, officials issued a warning to recreational users of Big Lagoon and the South Fork Eel River. Officials cited the deaths of nine dogs that swam in the contaminated waterways and the presence of microcystin in the stomachs of two animals that were examined. No other toxins were detected that could have caused the deaths according to a press release issued by Humboldt County Health and Human Services.

According to Corum, "Given our test results, Siskiyou County water quality officials should consider closing the lake to the public until an emergency response plan to algal blooms is devised – before someone gets sick or loses a pet to poisoning."

Children are at the greatest risk because of their small size and propensity to accidentally swallow water while swimming. If a swimming child swallowed half a cup of water from the reservoir, they would be exposed toxin levels almost 100 times the WHO allowable Total Daily Intake.

Corum suggests that users of the lake follow the WHO guidelines regarding blue-green algal blooms:

- Avoid areas with visible algae and/or scums. Direct contact and ingestion are associated with the greatest health risk.
- If no scums are visible, but water shows a strong greenish discoloration such that you cannot see your feet when standing knee deep (after sediment has settled) avoid bathing, immersion of head, and/or ingestion.
- Avoid waterskiing in visible scums or waters with a strong greenish coloration as described above because of the potentially substantial risk of exposure to aerosols.
- If sailing, sailboarding or undertaking any other activity likely to involve accidental immersion, wear clothing that is loose fitting in the openings. Use of wet suits for water sports may result in greater risk of rashes as the algal material trapped in the wet suit will be in contact with the skin for longer periods of time.
- After coming ashore, shower or wash to remove algal material.

Microcystis aeruginosa is native to the Klamath, but only in the reservoirs do conditions allow for massive blooms to occur, resulting in toxic levels of microcystin. These conditions include water rich in fertilizers, stagnation and warm water temperatures.

Editors' notes: Pictures of the sampling sites and a copy of lab results are available by contacting Craig Tucker at 530-627-3446 x27 or ctucker@karuk.us.

- 8/26 Confusion over potential health risk led to Siskiyou Daily article entitled: "Health risks of blue-green algae were overstated".

Health risks of blue-green algae were overstated

- 9/2 OEHHA memo: "COMMENTS ON THE CYANOBACTERIAL/MICROCYSTIN TOXIN SUMMER 2005 WATER SAMPLING RESULTS FOR THE COPCO/IRONGATE RESERVOIR" distributed. **Confirms that reservoir conditions pose a significant potential threat of adverse health affects in human and animals exposed through direct ingestion of contaminated water as well as incidental ingestion during recreational water activities and bathing.**

MEMORANDUM

TO:	**Matt St. John** **North Coast Regional Water Quality Control Board** 5550 Skylane Blvd., Suite A Santa Rosa, California 95403
VIA:	David M. Siegel, Ph.D., Chief Integrated Risk Assessment Branch
FROM:	Karlyn Black Kaley, Ph.D., D.A.B.T., Staff Toxicologist Applied Risk Assessment Unit
DATE:	September 1, 2005
SUBJECT:	COMMENTS ON THE CYANOBACTERIAL/MICROCYSTIN TOXIN SUMMER 2005 WATER SAMPLING RESULTS FOR THE COPCO/IRONGATE RESERVOIR.

As you have requested we have briefly reviewed the water sampling data found in the following first three documents. We have referenced the later two documents as part of our review as well.

1) memo dated August 18, 2005 re: Copco Lake Toxic Cyanobacteria Results to Karuk Tribe/NCWQCB from Jacob Kann, Ph.D.;
2) memo dated August 19, 2005 re: Copco/Irongate Reservoir Toxic Cyanobacteria Results: followup to Karuk Tribe/SWRCB/NCWQCB from Jacob Kann, Ph.D.;
3) memo dated August 30, 2005 re: Copco/Irongate Reservoir Toxic Cyanobacteria Results: 7/26-27 to Karuk Tribe/SWRCB/NCWQCB from Jacob Kann, Ph.D.;
4) 1999 World Health Organization, Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management, Ed. I. Chorus and J. Bartrum (html version found at: http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/); and,
5) World Health Organization Guidelines for Drinking Water Quality, 3rd Edition (html version found at: http://www.who.int/water_sanitation_health/dwq/gdwq3/en/index.html).

Given the time frame of less than two weeks for review, it was not possible for us to conduct a comprehensive risk analysis or assessment of the potential microcystin toxin exposure situation you have presented. However, based on the data you have presented, we can offer with confidence the following public health statement and supporting observations:

The *Microcystis aeruginosa* cyanobacteria levels and resulting microcystin toxin concentrations detected in water samples collected from both shoreline and open water locations in the Copco and Irongate Reservoirs in California pose a significant potential threat of adverse health affects in human and animals exposed through direct ingestion of contaminated water as well as incidental ingestion during recreational water activities and bathing.

<u>Adverse Health Effects</u>

Health effects that might be expected to be observed—following exposure to the microcystin toxin levels detected in the water samples reviewed—could range from mild non-life threatening skin conditions to permanent organ impairment and death, depending on exposure. More specifically, depending on exposure concentration, duration and individual sensitivity, symptoms could include mild to severe eye and ear irritation, allergic skin rash, mouth ulcers, fever, cold/flu like symptoms, vomiting, diarrhea, pneumonia, liver damage, kidney damage, complete liver failure, increased incidence of liver cancer and death. Children and animals are at greatest risk of serious life threatening affects because of their smaller body size and higher water ingestion rates.

World Health Organization Risk Levels

The World Health Organization (WHO) has established a Tolerable Daily Intake (TDI) as well as Guideline Values (GV's) for microcystin toxin in water. These are useful in evaluating potential risk of adverse health impacts from exposure via drinking water as well as recreational water activities. The TDI applies primarily to drinking water, while the GV's have been developed to specifically address the probability of adverse effects occurring in individuals exposed to contaminated water during specific water use scenarios. GV's have been developed for drinking water consumption as well as recreational water exposure.

According to WHO, a TDI is the amount of a potentially harmful substance that can be consumed daily, via ingestion, over a lifetime, with negligible risk of adverse health effects. TDI's are based on scientific data and controlled laboratory studies of observed adverse health impacts. The TDI for microcystin in this case was based on observed acute effects on the liver. The primary study used to develop the TDI is a 13-week oral ingestion mouse study. Because of lack of data, no long term chronic effects or carcinogenicity potential was used in the development of this TDI. Although TDI's do not account for multiple routes of exposure or cumulative risk due to exposure to multiple toxins, they are highly valuable in assessing the potential risk of adverse health effects from a single toxin. **The WHO TDI for microcystin toxin is 0.04 μg/kg body weight.**

WHO guideline values represent a scientific consensus, based on broad international participation, of the health risk to humans associated with exposure to microbes and chemicals found in water. For recreational water exposure GV's are defined at three primary concentration levels: *mild or low*, *moderate* and *high probability* of risk for adverse health impacts if exposed at a given toxin concentration. GV's are calculated values. They are derived using the TDI for a given chemical along with a persons' average body weight and the estimated amount of contaminated water that may be ingested on a daily basis during a given activity. GV's do not take into account health risks that may be attributed to other routes of exposure, such as aerosol inhalation or skin contact. **The WHO GV for moderate risk of adverse health effects from recreational exposure to microcystin in water is 20**

µg/liter (or a density of approximately 100,000 cyanobacteria cells per milliliter (ml) of water). The WHO GV for high risk is the presence of active algal scums, which can increase cell densities a 1000 to 1,000,000 fold.

The maximum *Microcystis aeruginosa* cyanobacteria density detected in the water samples reviewed was 11,402,943 cells/ml in the CRSH shoreline site sample. This sample had a laboratory detected microcystin toxin concentration of 667 µg/liter. Open water locations varied from 151,004 to 916,548 cells/ml. We understand that it is possible that higher concentrations of microcystin toxin than those detected in these samples may exist in other areas of these reservoirs. The presence of active scum may suggest a higher risk of adverse health effects for humans and animals exposed along shorelines. However, using only the data provided, if we take the maximum detected microcystin value of 667 µg/liter and compare it to the WHO GV for moderate risk of adverse health impacts for exposure to microcystin toxin in water, we can confirm your conclusion that microcystin toxin levels in this sample are 33 times that identified by WHO as posing a moderate risk of adverse health impact for recreational waters. WHO recommends taking some kind of mitigating action to reduce or eliminate human exposure when microcystin toxin concentrations are found at or above a moderate risk GV level of 20 µg/liter.

Recreational Incidental Ingestion Levels

Using the maximum detected toxin value reported above, the WHO values mentioned previously, and a number of general assumptions, we also calculated potential human exposure based on incidental ingestion of contaminated water during recreational water activities and bathing (i.e. swimming).

Adult Incidental Ingestion: For a 60 kilogram (kg) adult, incidentally ingesting 100 mls of contaminated water in any given day, the amount of microcystin toxin consumed would be 1.11 µg/kg body weight. This amount is 28 times greater than the accepted WHO Tolerable Daily Intake value of 0.04 µg/kg body weight. This calculation is based on a single one-hour "swimming event" per day. More swimming events or activities of longer duration could result in greater exposure.

Child Incidental Ingestion: With respect to children that may be exposed to microcystin at these levels there is an even greater potential health concern. For a 15 kilogram (kg) child (roughly 3 years of age), incidentally ingesting an estimated 250 mls of contaminated water in any one "swimming event" on any given day, the amount of microcystin toxin consumed would be 11.1 µg/kg body weight. This amount of microcystin toxin is 278 times greater than the accepted WHO Tolerable Daily Intake value of 0.04 µg/kg body weight. As with adults, more swimming events or activities of longer duration could result in greater exposure.

Exposure Routes During Recreational Activities

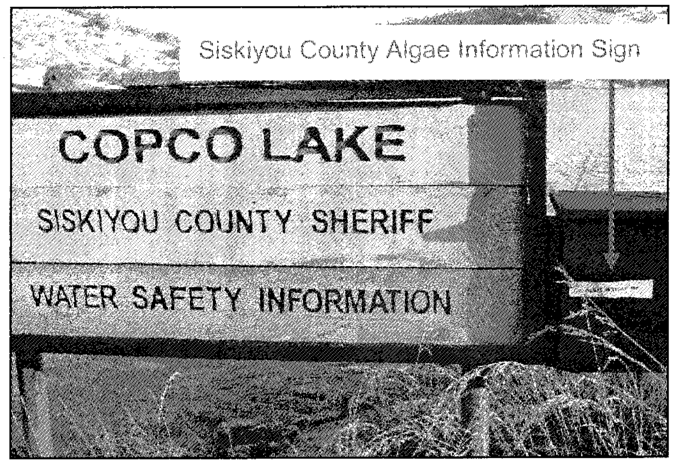
There are three main routes of exposure from recreational bathing and participation in water sports in waters contaminated with cyanobacteria and subsequent microcystin toxins. These include: 1) direct contact with exposed skin including the highly sensitive ear, eye, nose and throat membranes, 2) accidental or intentionally swallowing (oral ingestion), and 3) inhalation of contaminated water aerosols. Given the data presented and the risk values available, we can practically address only the potential risk associated with ingestion exposure in this limited review. Clearly the greatest risk of adverse affects to humans and animals would be associated with direct deliberate ingestion of contaminated water as a source of drinking water. However, incidental ingestion could also present a significant risk, especially for small children, in recreational settings. Ways to minimize or prevent all routes of exposures to contaminated reservoir water include prohibiting use of the water body as a source of drinking water and reducing contact with contaminated water by limiting and/or prohibiting recreational access.

Thank you for the opportunity to comment on the data set provided. If you have any questions please feel free to call me at (916) 323-2808.

cc: George V. Alexeeff, Ph.D., D.A.B.T.
Deputy Director for Scientific Affairs
Office of Environmental Health Hazard Assessment

Barbara Washburn, Ph.D.
Office of Environmental Health Hazard Assessment

- 9/7 Boxes with brochures at some recreation areas were seen labeled with pieces of paper saying "Algae Information".



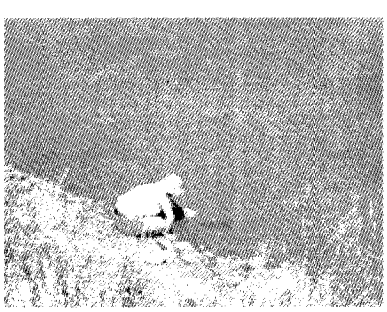
- 9/30 SWRCB, EPA, and Karuk Tribe issued press release "Federal, Tribal and State Authorities Advise Caution on Dangerous Klamath River Algae".

U.S. Environmental Protection Agency

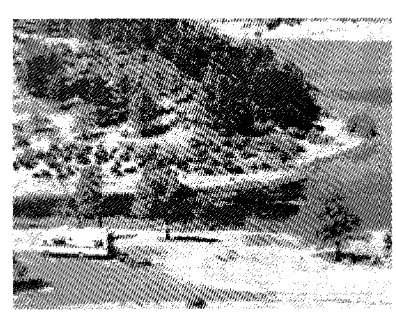
Region 9: News Releases

Federal, state and tribal authorities advise caution on dangerous Klamath River algae

For Immediate Release: September 30, 2005
Contact: Mark Merchant, U.S. EPA, (415) 947-4297; or William L. Rukeyser, California State Water Resources Control Board, (916) 341-7365
Press Office Main Line: (415) 947-8700 SAN FRANCISCO –In response to the emergence of



Water samples collected in Copco and Iron Gate reservoirs on the Klamath River have shown high levels of toxic blue-green algae.



The Klamath River is a popular recreation area on the California-Oregon border. (Photo credit: State Water Resources Control Board)

dangerous algal blooms in the Klamath River in California, the Karuk Tribe, the North Coast Regional Water Board and the U.S. Environmental Protection Agency are joining other local, state and federal agencies in warning residents and recreational users of the river to use caution when near such blooms.

"This algae produces toxins that pose a significant potential public health concern. We advise people to avoid all direct contact with Klamath River water while the bloom is occurring." said Alexis Strauss, Water Division director of the EPA's regional office in San Francisco.

Water samples taken over the past two months from Copco and Iron Gate Reservoirs – located on the Klamath near the Oregon border – have revealed high levels of the toxic blue-green alga Microcystis aeruginosa. Blooms of Microcystis aeruginosa, which often occur between June and September, can look like green, blue-green, white or brown foam, scum or mats floating on the water. They have been found as far as 125 miles downstream of the reservoirs.

The Klamath River is rich in nutrients that support the growth of the blue-green algae. Warm and calm surface water created by Iron Gate and Copco Reservoirs provide an ideal environment for the growth of large algal blooms. The extent of the blooms, and their toxicity, were not known until studies were conducted this year by the Karuk Tribe.

"In August, we found levels of Microcystis aeruginosa as high as 46.8 million cells/ml along the shoreline and 8.9 millions cells/ml on the open water. These levels exceed the World Health Organization (WHO) standard for recreational use by 468 and 89 times, respectively," explained Susan Corum, the Water Resources Coordinator for the Karuk Tribe's Department of Natural Resources. "Microcystin toxin produced by the blooms in these locations was 1571.7 and 436.9 µg/L; exceeding the WHO Tolerable Daily Intake level by 217 and 60.3 times respectively. These levels are among the highest recorded in the United States."

According to California's Office of Environmental Health Hazard Assessment (OEHHA), the U.S. EPA, the Karuk Tribe and Water Board, the Microcystis aeruginosa and resulting microcystin toxin pose a significant potential health threat to humans and animals exposed through direct ingestion of contaminated water or incidental ingestion during recreational water activities and bathing.

"The public needs to take the microcystin toxin in this algae seriously," said Catherine Kuhlman, Executive Officer of the North Coast Water Board. "The levels of algae and associated toxins measured in parts of the river are high enough to pose health risks to anyone drinking or bathing in the water, particularly children and animals."

Studies of the possible health effects of exposure to Microcystis aeruginosa and its microcystin toxin in the Klamath's waters range from mild, non-life threatening skin conditions to permanent organ impairment and death depending upon exposure time and intensity.

Symptoms could include mild to severe eye irritation, allergic skin rash, mouth ulcers, fever, cold and flu-like symptoms, vomiting, diarrhea, kidney damage, liver damage or complete failure, and death.

Children and animals are at the greatest risk of adverse effects, due to their smaller body size and higher water ingestion rates.

As pets and other domestic animals could drink contaminated water, pets and livestock should be kept away from the water.

Algae blooms, such as this one at Mallard Cove on Copco Reservoir, produce toxins that could harm people and animals. (Photo credit: State Water Resources Control Board)

There are three main ways to be exposed to Microcystis aeruginosa and subsequent microcystin toxins in contaminated waters:

direct contact to exposed skin or to the highly sensitive
membranes of the ear, eye, nose and throat;
accidental or intentional swallowing; and;
inhalation of contaminated water aerosols.

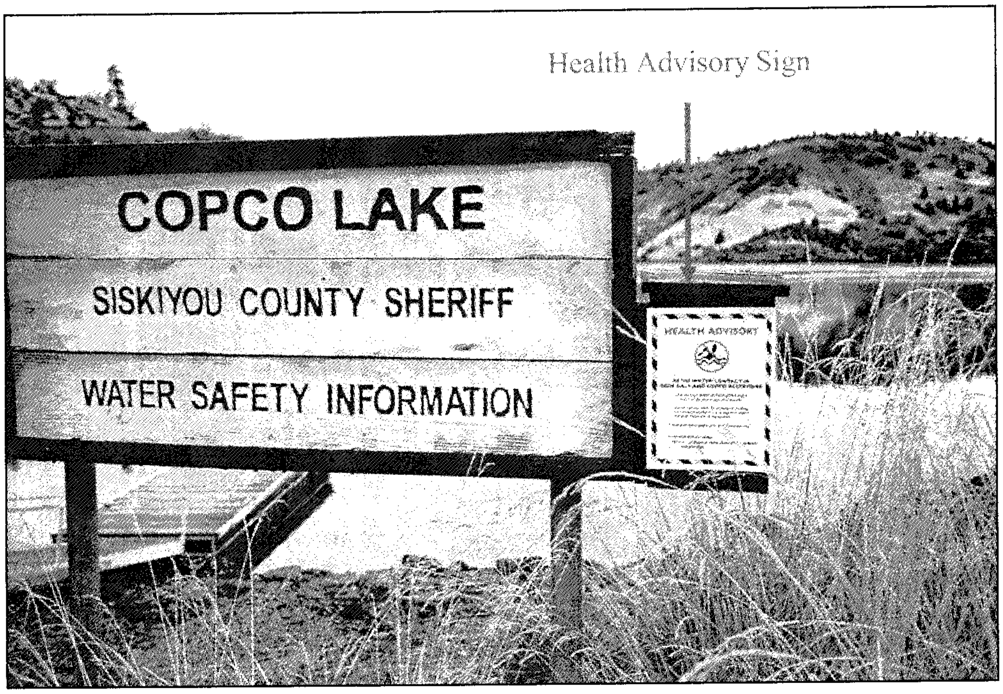
A full-grown adult ingesting 3.4 ounces of contaminated water in a given day would be exposed to levels 28 times greater than the accepted World Health Organization's Tolerable Daily Intake value. This calculation is based on a single one-hour "swimming event" per day. More swimming events or activities of longer duration could result in greater exposure.

For an average-size child who is 3-years-old, ingesting slightly more than a measuring cup of contaminated water in any one "swimming event" would be the equivalent of 278 times the accepted WHO Tolerable Daily Intake value. As with adults, more swimming events or activities of longer duration could result in greater exposure.

Local, state, tribal and federal health and environmental agencies recommend that people not drink or cook with contaminated waters. You should avoid or minimize contact with contaminated waters. It is best of stay out of the water near algal blooms and to keep pets away. If you do come in contact with the water, wash thoroughly with clean water. Avoid eating fish caught during an algal bloom. If you do, fishermen should clean the fish with fresh water and dispose of the innards away from the river or where animals could eat them; Avoid irrigation with contaminated water; Report dead or distressed wildlife along the shoreline to local, state or tribal authorities.

For more information, visit: The 1999 World Health Organization, Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management at:
http://www.who.int/water_sanitation_health/resourcesquality/toxicyanbact/en/ and,
World Health Organization Guidelines for Drinking Water Quality, 3rd Edition at:
http://www.who.int/water_sanitation_health/dwq/gdwq3/en/index.html

- 10/6 Health Advisory Warning signs were posted at Copco and Iron Gate Reservoirs by SWRCB and NCRWQCB.



- 10/13 Yurok Tribe issued press release on MSAE and microcystin in the Klamath River.

PRESS RELEASE
13 October 2005

FOR IMMEDIATE RELEASE

The Yurok Tribe announced today that recent laboratory testing for toxic strains of blue-green algae have indicated that levels of microcystis in the Klamath River between Weitchpec and the mouth of the river have fallen below World Health Organization Standards for human health risk from recreational contact. Recent cooler weather and the onset of fall rains have been attributed to the die-off of blue green algae blooms and the reduction in algal toxins sampled in the lower river.

As levels of blue-green algae above Irongate and Copco dams continue to exceed World Health Organization Standards, the Yurok Tribe is continuing to monitor water quality in the lower Klamath River but has posted notices at common access points and gathering places indicating that water quality in the lower river has significantly improved and is acceptable for recreation, including swimming.

"The Tribe is relieved that danger to human and animal health from toxic waters seems to have passed. We look forward to working with our partners in Klamath River water quality to effectively monitor blue-green algae and coordinate community responses in the coming year," said Chairman Howard McConnell.

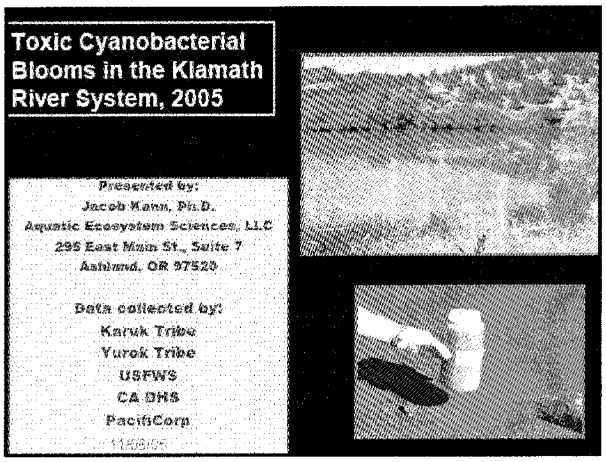
"Results of testing of adult salmon and steelhead tissues for residual microcystin content are still forthcoming from the laboratory," said environmental coordinator Laura Mayo, "As migrating salmon are not actively foraging for food during this time of year, the likelihood of any accumulation of toxin in fish tissues is minimal. As a precaution,

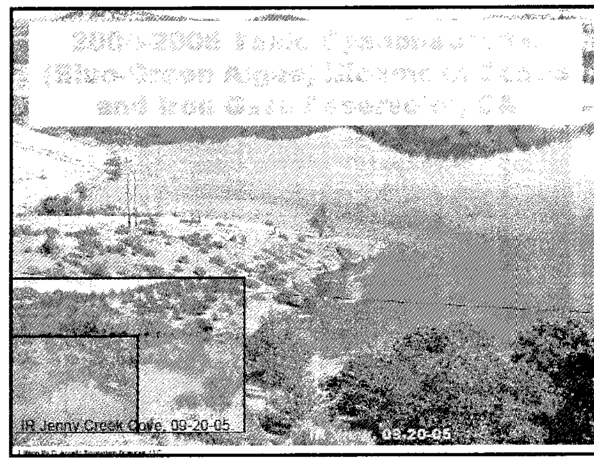
fishers are advised to remove the guts of any fish caught, especially the liver, and dispose of that tissue in a secure location, and to wash all edible parts of the fish with clean drinking water."

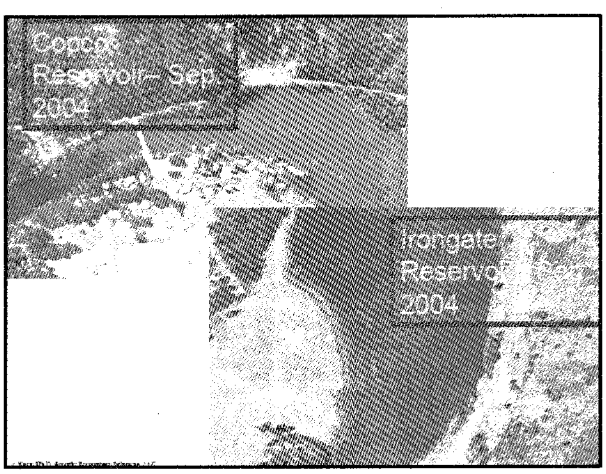
Because there are still microcystis cells in the waters of the Klamath, prolonged, closed contact with river waters is still not recommended. Types of contact not recommended include: standing in waterlogged boots or waders, or wearing a wetsuit in Klamath River waters for extended periods; contact with impacted waters in an enclosed space can break open live cells, releasing microcystin, and in addition, prolonged exposure to even minutely toxic waters can cause dermal reactions, such as inflammation or rash. Persons who have been exposed under such circumstances are advised to wash immediately with clean water and consult a health care professional if they experience any symptoms.

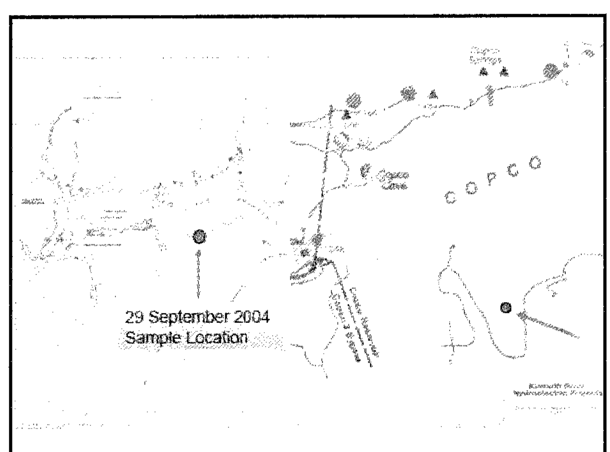
Community members with further questions are welcome to call the Yurok Tribe's microcystis information line at (707) 482-1350, extension 367.

- 11/2 MSAE bloom subsided in both Copco and Iron Gate Reservoirs. Levels of MSAE were below the WHO moderate risk level and microcystin levels were below the detection limit of .147 µb/L.


Toxic Cyanobacterial Blooms in the Klamath River System, 2005
Presented by:
Jacob Kann, Ph.D.
Aquatic Ecosystem Sciences, LLC
295 East Main St., Suite 7
Ashland, OR 97520
Data collected by:
Karuk Tribe
Yurok Tribe
USFWS
CA DHS
PacifiCorp


IR Jenny Creek Cove, 09-20-05
09-20-05


Copco Reservoir– Sep 2004
Irongate
2004


COPCO
29 September 2004
Sample Location

Phytoplankton Sample Analysis

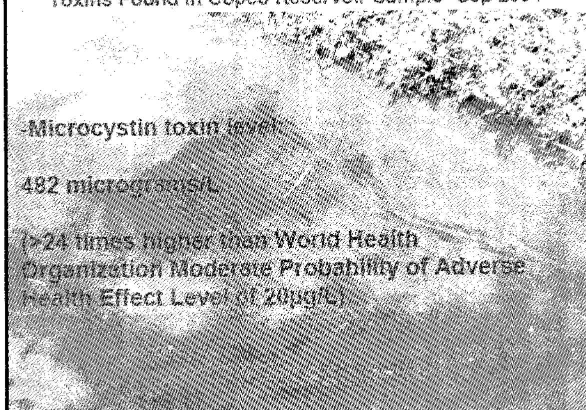
Sample: Copco Res
Sample Station: JSH
Sample Depth:
Sample Date: 29-Sep-04
Total Density (#/mL): 132,794
Total Biovolume (um³/mL): 45,273,384

Species	Density Colonies #/mL	Density Percent	Biovol. um³/mL	Biovol. Percent
Nitzschia palea	120,267	90.6	21,648,000	47.8
Microcystis aeruginosa	6,514	4.9	15,269,858	33.7
Aphanizomenon flos-aquae	4,009	3.0	2,886,400	6.4
Melosira ambigua	501	0.4	4,722,471	10.4
Cryptomonas erosa	501	0.4	260,578	0.6
Nitzschia frustulum	501	0.4	60,133	0.1
Gomphonema ventricosum	501	0.4	425,944	0.9

Microcystis aeruginosa cells/mL =1,908,732

Aquatic Analysts
Sample ID: GW95

Toxins Found in Copco Reservoir Sample- Sep 2004



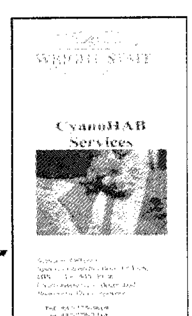
2005 Sampling

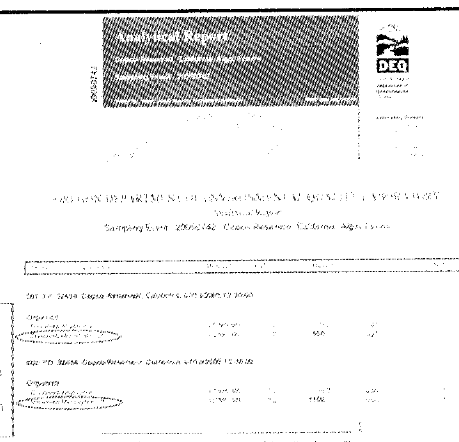
Biweekly Sampling for cell counts and toxin

Grab samples of surface algal material.

Cell counts: Samples preserved in Lugol's Iodine and Microscopic Analysis performed by Jim Sweet, Aquatic Analysts, White Salmon Washington

Microcystin Toxin Analysis: samples shipped on ice (over-night) air to Dr. Wayne Carmichael at WSU for ELISA test for microcystin concentration.

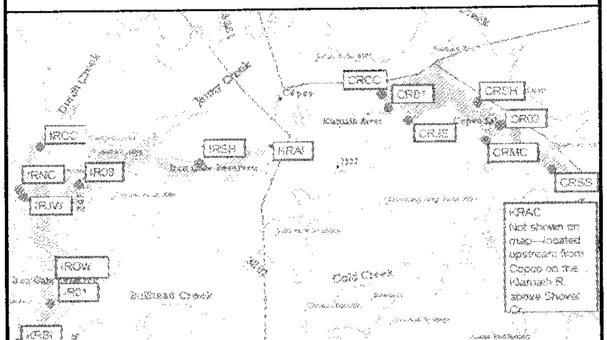




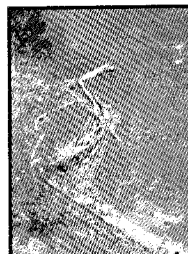
LCMS-MS Results showing prevalence of microcystin -LR

EPA1152

Copco and Iron Gate Reservoir Sampling Locations



J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC



Copco shoreline from road (~12 ft above water level) 7-13-05

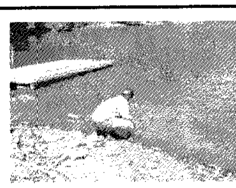
Copco shoreline standing on shoreline 7-13-05

Copco shoreline close up 7-13-05

J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC

CRMC: 8-10-05

1,427,215 cells/ml *Microcystis*



CRCC: 8-10-05

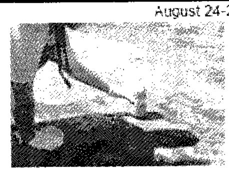
263,963 cells/ml *Microcystis*

IRNC: 8-11-05

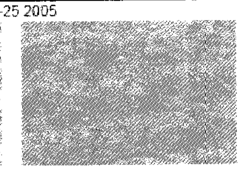
5,350,847 cells/ml *Microcystis*

J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC

August 24-25 2005



IRJW-
sample:
17,458,065

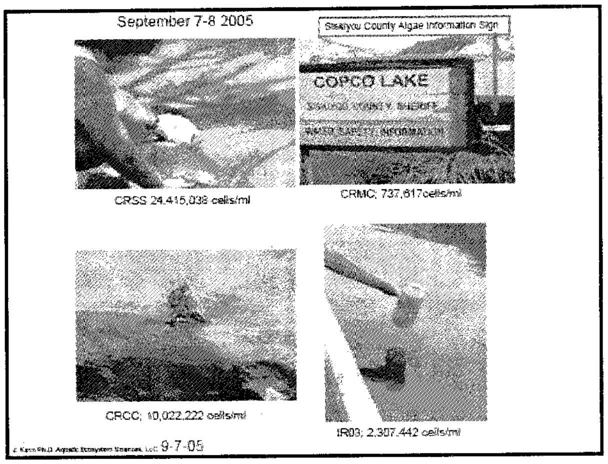


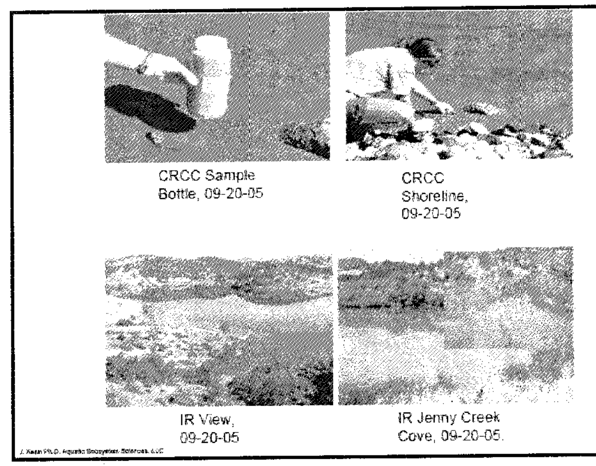
IRJW

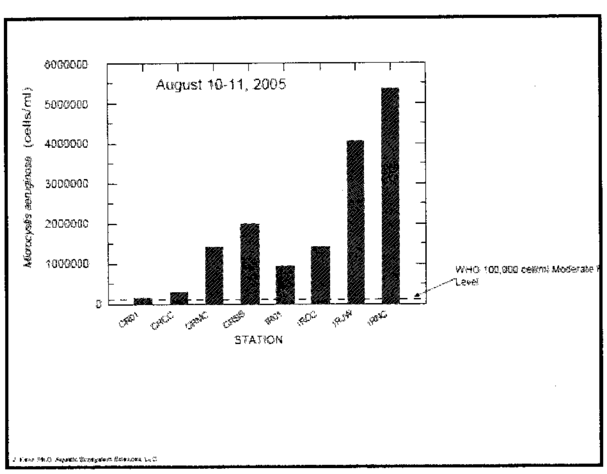
IROW-
8,944,366
cells/ml

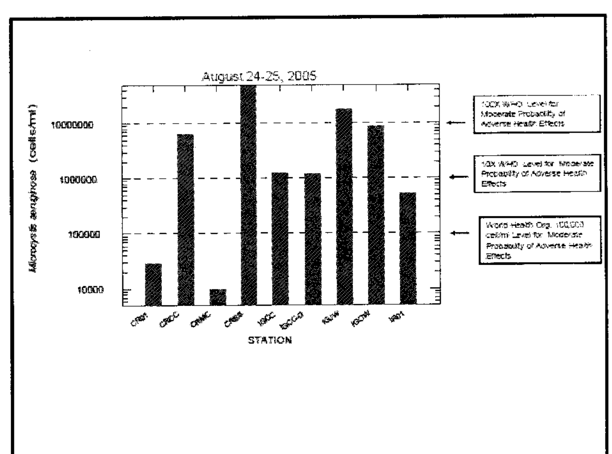
IronGate
Water Skier
8-25-05

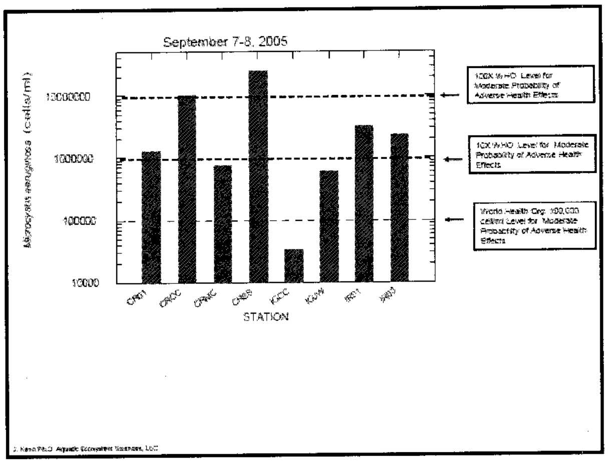
J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC

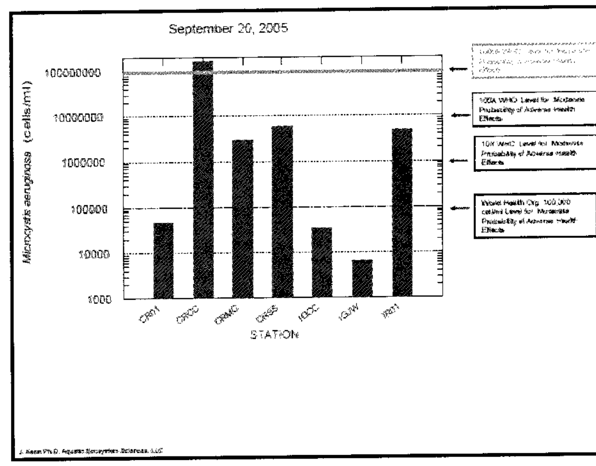

September 7-8 2005
Siskiyou County Algae Information Sign
COPCO LAKE
CRSS 24,415,038 cells/ml
CRMC; 737,617cells/ml
CRCC; 10,022,222 cells/ml
IR03; 2,307,442 cells/ml
9-7-05

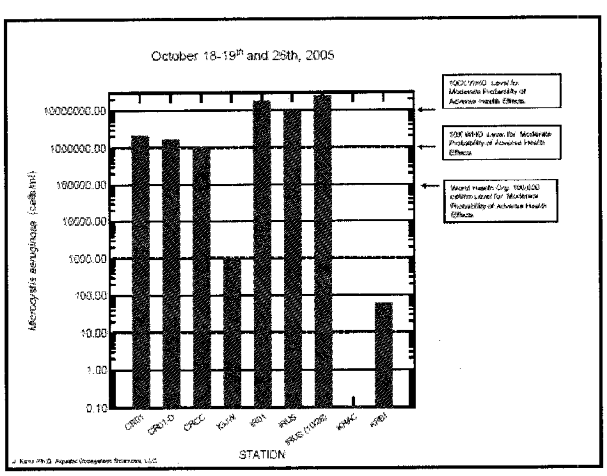

CRCC Sample
Bottle, 09-20-05
CRCC
Shoreline,
09-20-05
IR View,
09-20-05
IR Jenny Creek
Cove, 09-20-05

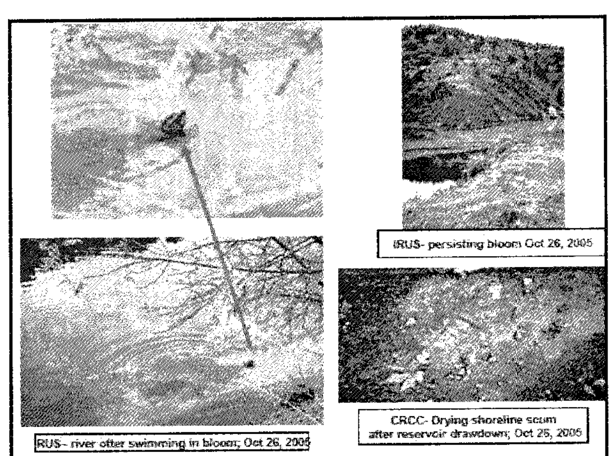

August 10-11, 2005
Microcystis aeruginosa (cells/ml)
6000000
5000000
4000000
3000000
2000000
1000000
0
STATION
WHO 100,000 cells/ml Moderate
Level

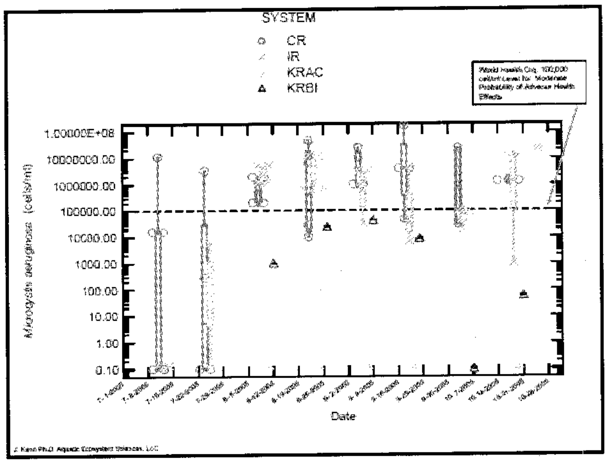

August 24-25, 2005
Microcystis aeruginosa (cells/ml)
10000000
1000000
100000
10000
STATION
100X WHO Level for Moderate Probability of Adverse Health Effects
10X WHO Level for Moderate Probability of Adverse Health Effects
World Health Org. 100,000 cell/ml Level for Moderate Probability of Adverse Health Effects

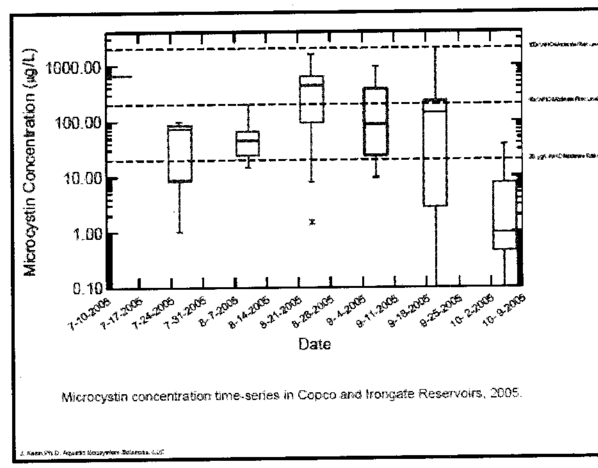

September 7-8, 2005
Microcystis aeruginosa (cells/ml)
10000000
1000000
100000
10000
STATION
100X WHO Level for Moderate Probability of Adverse Health Effects
10X WHO Level for Moderate Probability of Adverse Health Effects
World Health Org. 100,000 cells/ml Level for Moderate Probability of Adverse Health Effects
J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC


September 20, 2005
Microcystis aeruginosa (cells/ml)
100000000
10000000
1000000
100000
10000
1000
STATION
100X WHO Level for Moderate Probability of Adverse Health Effects
10X WHO Level for Moderate Probability of Adverse Health Effects
World Health Org. 100,000 cells/ml Level for Moderate Probability of Adverse Health Effects
J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC


October 18-19th and 26th, 2005
Microcystis aeruginosa (cells/ml)
10000000.00
1000000.00
100000.00
10000.00
1000.00
100.00
10.00
1.00
0.10
STATION
100X WHO Level for Moderate Probability of Adverse Health Effects
10X WHO Level for Moderate Probability of Adverse Health Effects
World Health Org. 100,000 cells/ml Level for Moderate Probability of Adverse Health Effects
J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC

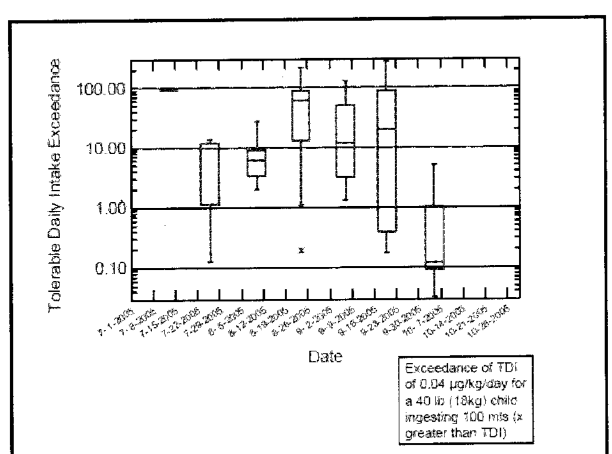

IRUS- persisting bloom Oct 26, 2005
RUS– river otter swimming in bloom; Oct 26, 2005
CRCC- Drying shoreline scum
after reservoir drawdown; Oct 25, 2005
J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC



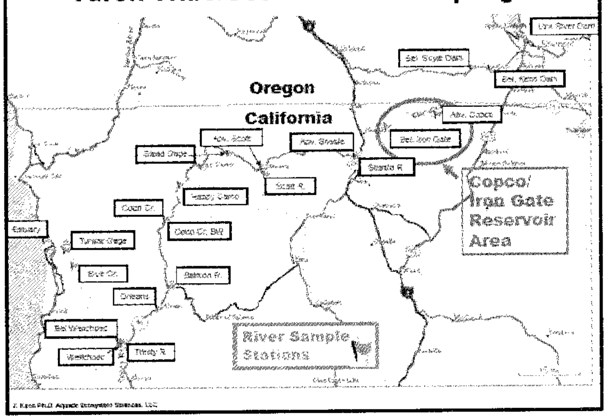


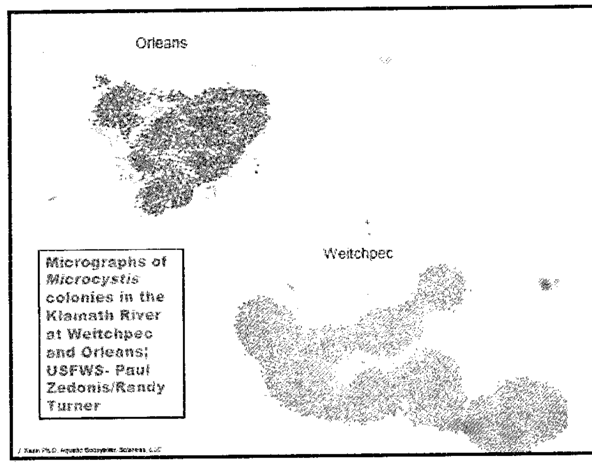
DATE	STATION NAME	DEPTH	Microcystis aeruginosa (cells/ml)	Microcystin Total (µg/L)	Exceedance of moderate risk level of 100,000 cells/ml Microcystis (x greater than 100 cells/ml)	Exceedance of moderate risk level of 20 µg/L microcystin (x greater than 20 µg/L)	Exceedance of TDI of 0.04 µg/kg/day for a 40 lb (18kg) child ingesting 100 mls (x greater than TDI)
9/28/04	CRJC	0	1,908,732	460	19	24	67
9/13/05	CRSH	0	11,403,843	697	114	35	58
7/26/05	CRCC	0	3,246,178	72.16	33	3.6	63.0
7/27/05	IRGB	0	5,534	0.92	0	0.05	0.13
7/27/05	IRBN	0	NA	66.36	NA	4.3	53.8
8/10/05	CRSI	0	151,094	90.35	2	4.3	22.6
8/10/05	CRCC	0	263,063	186.26	3	9.3	77.1
8/10/05	CRMC	0	1,437,275	36.58	14	1.8	8.1
8/10/05	CRBO	0	1,985,035	44.22	20	2.2	9.1
8/11/05	IRSI	0	916,543	16.23	9	0.8	3.2
8/11/05	IRCC	0	1,423,432	14.75	14	0.7	7.2
8/11/05	IRJW	0	4,058,006	46.65	41	2.3	6.4
8/11/05	IRHC	0	5,339,847	46.70	54	2.3	6.4
8/24/05	CRCC	0	6,415,363	644.2	64	32.0	84.4
8/24/05	CRMC	0	9,526	1.4	0	0.1	0.2
8/24/05	CRBO	0	48,434,813	1671.7	486	75.6	211.1
8/24/05	CRSI	0	28,168	8	0	0.4	1.1
8/25/05	IRSI	0	326,729	846.4	3	30.3	28.1
8/25/05	IRCC	0	1,257,526	93.8	13	4.7	13.9
8/25/05	IRCC-D	0	1,184,487	94.6	12	4.7	13.1
8/25/05	IRJW	0	17,453,085	812.2	175	31.6	87.3
8/25/05	IRCW	0	8,544,396	436.8	86	21.6	90.3

J. Kann Ph.D. Aquatic Ecosystem Sciences, LLC



Yurok Tribe/USFWS River Sampling



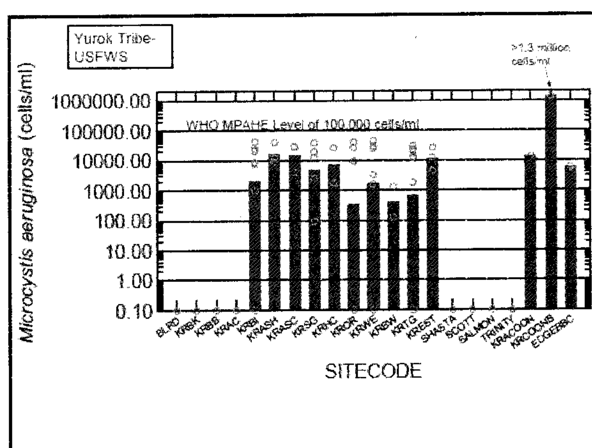


Micrographs of *Microcystis* colonies in the Klamath River at Weitchpec and Orleans; USFWS- Paul Zedonis/Randy Turner

Station Codes

Below Link River Dam	BLRD
Below Keno Dam	KRBK
Below JC Boyle Dam	KRBB
KRAC	KRAC
KR @ Below IG	KRBI
Abv Shasta R.	KRASH
Abv Scott R.	KRASC
Seiad Gage	KRSG
Happy Camp	KRHC
Orleans	KROR

Weitchpec (abv TR)	KRWE
Below Weitchpec	KRBW
Turwar Gage	KRTG
KR Estuary	KREST
Shasta R.	SHASTA
Scott R.	SCOTT
Salmon R.	SALMON
Trinity R.	TRINITY
KR Above Coon Creek River Access	KRACOON
Backwater pool at Coon Creek River Access	KRCOONB
Edgewater Below Blue Creek	EDGEBBC



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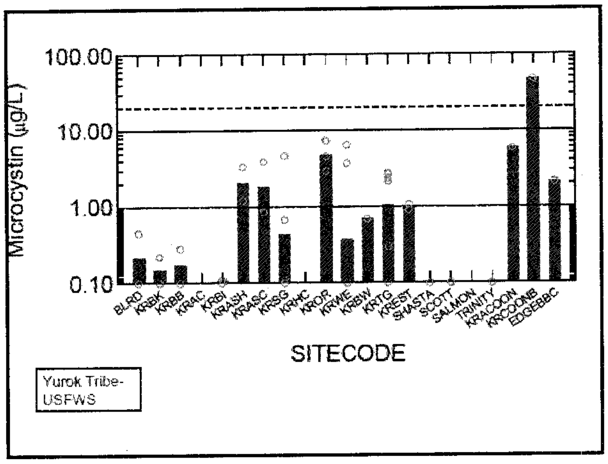

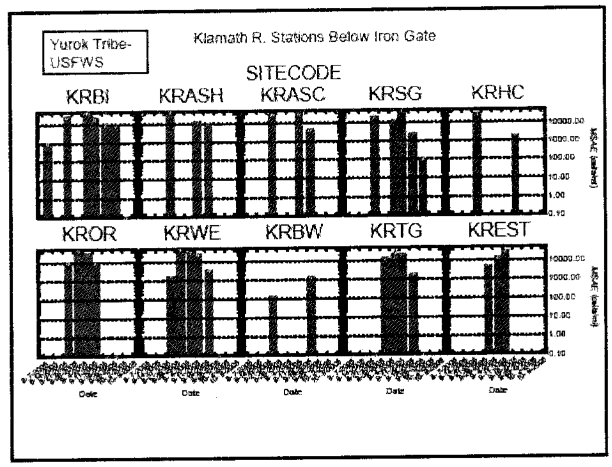

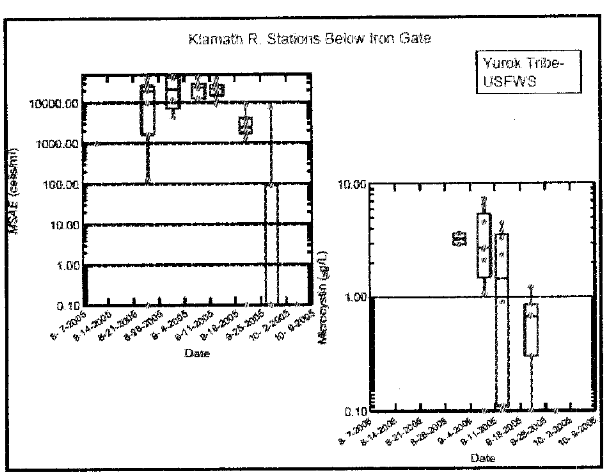

Fish Tissue Analyses - Yurok Tribe Environmental and Fisheries Program

Site Location Information	13-Sep	14-Sep	30-Sep	3-Oct
Site Name	Microcystin Concentration (ppm or µg/g)	Microcystin Concentration (ppm or µg/g)	Microcystin Concentration (ppm or µg/g)	Microcystin Concentration (ppm or µg/g)
Weitchpec Adult Salmon Liver	0.00 (BDL)¹	0.00 (BDL)		
Weitchpec Adult Salmon Liver		0.00 (BDL)		
Weitchpec Adult Salmon Muscle		0.00 (BDL)		
Weitchpec Adult Salmon Muscle		0.00 (BDL)		
Iron Gate Hatchery Adult Salmon Tissue - Male			0.00 (BDL)	
Iron Gate Hatchery Adult Salmon Tissue - Female			0.00 (BDL)	
Iron Gate Hatchery Adult Salmon Liver - Male			0.00 (BDL)	
Iron Gate Hatchery Adult Salmon Liver - Female			0.00 (BDL)	
Weitchpec Steelhead Tissue - Adult				0.00 (BDL)
Weitchpec Steelhead Tissue - Half-Pounder				0.00 (BDL)
Weitchpec Steelhead Liver - Adult				TRACE [illegible] ppb
Weitchpec Steelhead Liver - Half-Pounder				[illegible]

¹BDL= below detection limit of 0.147 ppb; ²Limit of quantification=0.175 ppb

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EPA1158

Fish Tissue Analyses - Yurok Tribe Environmental and Fisheries Programs

Weitchpec Steelhead Liver - Adult	TRACE: 0.17 ppb
Weitchpec Steelhead Liver - Half-Pounder	0.84 ppm or µg/g

Fish Summary:

- **Of 9 adult salmon liver and muscle samples from Weitchpec and Iron Gate Hatchery all were below the detection limit of 0.147 ppb.**
- **Of 2 Steelhead (one adult and one ½ pounder) tissue samples from Weitchpec both were below the detection limit of 0.147 ppb.**
- **Of 2 Steelhead (one adult and one half-pounder) liver samples from Weitchpec the adult had a trace amount of 0.17 ppb and the ½ pounder had 0.84 ppm (µg/g).**

Conclusion: Low to trace quantities of microcystin in Steelhead livers in the lower Klamath River show that these fish were exposed to toxin levels in the river environment, and indicate the potential for toxin uptake to occur.

Note: Steelhead residing in the Klamath River at the time of sampling would have increased exposure time relative to salmon.

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New Zealand Ecological Society Annual Conference
28 August – 1 September 2005

Talk: **Accumulation of microcystins (a toxin produced by cyanobacteria) in freshwater organisms**

Susie Wood1, L. R. Briggs2, J. Sprosen2, J. R. Ruck3, R. G. Wear4, P. T. Holland5, and M. Bloxham6

1 Cawthron Institute, Nelson
2 Toxinology, AgResearch, Ruakura
3 Institute of Food, Nutrition and Human Health, Massey University at Wellington
4 School of Biological Sciences, Victoria University of Wellington
5 Cawthron Institute, Nelson
6 Environment Bay of Plenty, Whakatane

Abstract: Microcystins are hepatotoxins produced by some cyanobacteria (blue-green algae) species. Microcystins inhibit protein phosphatase types 1 and 2A in affected organisms and have been implicated in human, bird, wild animal and livestock fatalities. Accumulation of microcystins in rainbow trout (Oncorhynchus mykiss) and freshwater mussels (Hyridella menziesi) in Lakes Rotoiti and Rotoehu (Rotorua) were investigated. Hatchery rainbow trout were added to an enclosure in Lake Rotoiti where levels of microcystins in the water could be closely monitored, and trout that were free to roam in th entire area of each lake were also included in the study. Freshwater mussels were suspended sub-surface in cages in the enclosure. Rainbow trout liver and muscle tissue and the tissues of mussels were analyzed for microcystins using the ADDA-ELISA metho and selected samples were analysed using LC-MS. ELISA results confirmed the presence of microcystin immunoreactivity in rainbow trout liver and muscle tiss... and in freshwater mussels at levels of 12 79 g kg-1. The microcystin congeners: LR, Y RR, AR, FR, LA and WR were detected by LC-MS in the freshwater mussels but were not detected by in either the trout muscle or liver. The Daily Tolerable Intake limit of microcystins for human consumption recommended by the World Health Organisation is 0.04 g kg-1 day-1. Modelling was carried out for the human intakes of microcystin compounds from trout muscle and the potential health risks estimated, assuming the ADDA-ELISA was determining compounds of equivalent toxicity to microcystin-LR.

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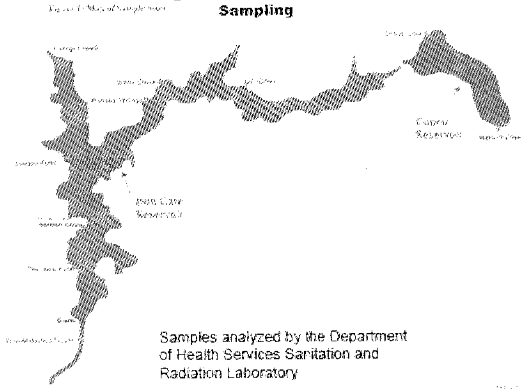
CA Dept. of Health Services, Division of Drinking Water and Environmental Management: 9/3/2005 Microcystin/Anatoxin-a Sampling



Samples analyzed by the Department of Health Services Sanitation and Radiation Laboratory

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CA DHS-DDWEM

Collector		Source Note: Water System No 4710007 Serves the City of Montague Near Lake Shastina	Anatoxin-a	MCLR
4741	T. Wiedemann	System No. 4710007 Treated (PAC filtrate)	<RL	<RL
4742	T. Wiedemann	System No. 4710007 Influent	<RL	<RL
4743	T. Wiedemann	Raw Water Pond	20	<RL
4743	T. Wiedemann	Raw Water Pond	19	<RL
4768	T. Wiedemann	System No. 4710007 Treated (PAC filtrate)	<RL	<RL
4769	T. Wiedemann	System No. 4710007 Treated (PAC filtrate)	<RL	<RL
4770	T. Wiedemann	System No. 4710007 Treated (PAC filtrate)	<RL	<RL
4771	T. Wiedemann	System No. 4710007 Influent	<RL	<RL
4772	T. Wiedemann	System No. 4710007 Influent	<RL	<RL
4773	T. Wiedemann	System No. 4710007 Influent	<RL	<RL
4628	T. Mackie	Klamath River (just downstream of Iron Gate Dam)	<RL	6.8
5502	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	<RL	7.9
5502	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	<RL	26
5502	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	<RL	30
5503	T. Mackie	Copco Reservoir - Copco Cove	<RL	33
5503	T. Mackie	Copco Reservoir - Copco Cove	<RL	21
5508	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	34	99
5508	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	33	111
5508	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	30	138
5509	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	25	155
5509	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	24	146
5509	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	22	221

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CA DHS-DDWEM

Toxin Conc. µg/L

Exceedance of TDI of 0.04 µg/kg/day for a 40 lb (18kg) child ingesting 100 mls (x greater than TDI)

Collector		Source	Anatoxin-a	MCLR		
4625	T. Mackie	Klamath River (just downstream of Iron Gate Dam)	<RL	6.8		1
5501	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	<RL	7.9		1
5502	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	<RL	26		4
5502	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	<RL	30		4
5503	T. Mackie	Copco Reservoir - Copco Cove	<RL	33		5
5503	T. Mackie	Copco Reservoir - Copco Cove	<RL	21		3
5508	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	34	99		14
5508	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	33	111		15
5508	T. Mackie	Iron Gate Reservoir - Overlook Park (South point 1)	30	136		19
5509	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	25	153		21
5509	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	24	148		20
5509	T. Mackie	Iron Gate Reservoir - Overlook Park (North point 2)	22	221		31

Anatoxin-a RL = 2 µg/L (ppb)

Microcystin LR RL = 0.3 ug/L (ppb)

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PacifiCorp Klamath River Phytoplankton Sampling 2001-2004

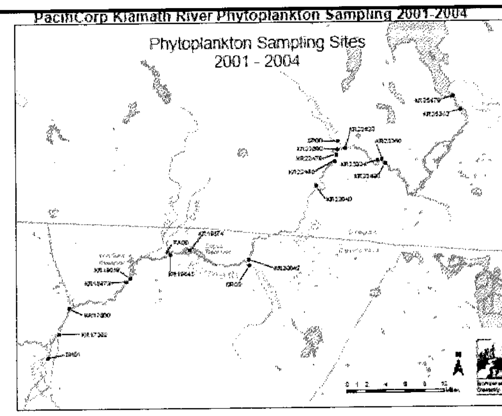

Figure 1. Location of phytoplankton collection sites in the vicinity of the Klamath Hydroelectric Project, 2001 - 2004.

PacifiCorp

Table 1. Phytoplankton sample sites in the vicinity of the Klamath Hydroelectric Project, 2001-2004.

Site ID[1]	River Mile	Latitude	Longitude	Site Name
KR17300	173.00	41.6362	-122.5829	Klamath River above Shasta River
KR17600	176.00	41.8301	-122.5937	Klamath River at I-5 Rest Area
KR18973	189.73	41.9310	-122.4423	Iron Gate dam Outflow
KR19019	190.19	41.9342	-122.4330	Iron Gate reservoir near dam
KR19645	196.45	41.9731	-122.3602	Copco 2 dam Outflow
KR19874	198.74	41.9794	-122.3333	Copco reservoir
KR20642	206.42	41.9721	-122.2016	Klamath River upstream of Shovel Creek
KR22040	220.40	42.0932	-122.0713	Klamath River upstream of J.C. Boyle Powerhouse
KR22460	224.60	42.1217	-122.0494	Klamath River below J.C. Boyle dam
KR22478	224.78	42.1229	-122.0470	J.C. Boyle reservoir at Log Boom
KR22600	226.00	42.1351	-122.0313	J.C. Boyle reservoir at Hwy 66 Bridge
KR22822	228.22	42.1469	-122.0154	Klamath River above J.C. Boyle reservoir
KR23334	233.34	42.1353	-121.9489	Keno dam Outflow
KR23360	233.60	42.1340	-121.9482	Keno reservoir at Log Boom
KR23490	234.90	42.1222	-121.9194	Klamath River at Keno Bridge (Hwy 66)
KR25312	253.12	42.2168	-121.7884	Link River at Mouth
KR25479	254.79	42.2383	-121.8053	Upper Klamath Lake at Freemont St Bridge
SP00	0	42.1526	-122.0325	Spencer Creek near Mouth
SH00	0	41.9724	-122.3027	Shovel Creek near Mouth
FA00	0	41.9687	-122.3653	Fall Creek near Mouth
SH01	1	41.8231	-122.5944	Shasta River near Mouth

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Abudance of *Microcystis aeruginosa* and *Aphanizomenon flos-aquae* in Samples Collected from Copco and Iron Gate Reservoirs on August 23, 2005.

Location	Sample ID	Species	Abundance (cells/mL)
Copco (KR19874)	KR5128	*Microcystis aeruginosa*	130,871
1 m grab sample		*Aphanizomenon flos-aquae*	100,670
Iron Gate (KR19019)	KR5129	*Microcystis aeruginosa*	39,711
10m integrated		*Aphanizomenon flos-aquae*	23,259
Iron Gate (KR19019)	IGSURF	*Microcystis aeruginosa*	6,687,729 (see note below)
Surface grab sample		*Aphanizomenon flos-aquae*	Not observed*
Iron Gate (KR19019)	KR5133	*Microcystis aeruginosa*	1,318
1 m grab sample		*Aphanizomenon flos-aquae*	Not observed
Iron Gate (KR19019)	KR5134	*Microcystis aeruginosa*	68,428
10 m integrated		*Aphanizomenon flos-aquae*	Not observed
Below Iron Gate Dam	KR5126	*Microcystis aeruginosa*	33,063
(KR19873)		*Aphanizomenon flos-aquae*	51

*Present at less than 1 percent of the total sample biovolume

Note: This data (Iron Gate KR 19019, IGSURF) is from an additional (non-routine) sample that was taken from the most concentrated area of a localized algal bloom at the surface of the water based on observed conditions present at the time of sampling.

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PacifiCorp: 2001-2002

DATE	STATION	RM	DEPTH	SLIDE	DENS
17-Oct-01	KR22478	224.72	3.0	FY58	5
14-Aug-02	KR19019	190.19	12	GI41	1
14-Aug-02	KR19645	196.45	0.5	GI40	5
10-Sep-02	KR18973	189.73	0.5	GI66	15
10-Sep-02	KR19015	190.19	0.5	GI65	67
10-Sep-02	KR19645	196.45	0.5	GI72	9
10-Sep-02	KR19874	198.74	10 INT	GI70	17
10-Sep-02	KR20542	205.42	0.5	GI62	30
9-Oct-02	KR19645	196.45	0.5	GI37	52
9-Oct-02	KR19874	198.74	0.5	GI34	155

Note: Density (DENS) is reported in colonies/ml not as cells/ml

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PacifiCorp - 2003

DATE	STATION	RM	DEPTH	SLIDE	DENS
16-Jul-03	KR19019	190.19	10 INT	GL76	2
16-Jul-03	KR19874	198.74	0.1	GL65	28
19-Aug-03	KR19015	190.19	10 INT	GL90	27
19-Aug-03	KR19874	198.74	10 INT	GL75	492
19-Aug-03	KR19874	198.74	0.1	GL77	22,550
20-Aug-03	Lake Ewauna			GU25	24
20-Aug-03	Lake Ewauna			GU06	171
20-Aug-03	Lake Ewauna			GU05	131
20-Aug-03	Lake Ewauna			GU13	96
20-Aug-03	Lake Ewauna			GU15	152
20-Aug-03	Lake Ewauna			GU16	17
20-Aug-03	Lake Ewauna			GU21	[illegible]
20-Aug-03	Lake Ewauna			GU23	53
21-Aug-03	KR18973	189.73	0.5	GL89	65
21-Aug-03	KR19645	196.45	0.5	GL86	1,113
21-Aug-03	KR20642	206.42	0.5	GL87	9
21-Aug-03	KR23490	234.9	0.5	GL83	49
17-Sep-03	KR18973	189.73	0.5	GL00	34
17-Sep-03	KR19019	190.19	0.1	GU04	12
17-Sep-03	KR19019	190.19	10 INT	GU05	22
17-Sep-03	KR19645	196.45	0.5	GU03	54
17-Sep-03	KR19874	198.74	0.1	GU01	25
17-Sep-03	KR19874	198.74	10 INT	GU02	19
14-Oct-03	KR19874	198.74	10 INT	GU46	5

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PacifiCorp - 2004

DATE	STATION	RM	DEPTH	SLIDE	DENS
20-Jul-04	KR18973	189.73	0.5	HF33	3
21-Jul-04	KR19015	190.19	0.5	HF43	7
21-Jul-04	KR19019	190.19	5	HF44	1
21-Jul-04	KR19019	190.19	10 INT	HF46	9
21-Jul-04	KR19874	198.74	0.5	HF41	9
10-Aug-04	KR22040	220.4	0.5	HF48P	105
17-Aug-04	KR17600	176	0.5	HF75P	18
17-Aug-04	KR18973	189.73	0.5	HF74P	75
17-Aug-04	KR19645	196.45	0.5	HF73P	223
17-Aug-04	KR22460	224.6	0.5	HF69P	455
20-Aug-04	KR19019	190.19	0.5	HF79P	105
20-Aug-04	KR19015	190.19	10 INT	HF80P	117
20-Aug-04	KR19874	198.74	0.5	HF76	220
20-Aug-04	KR19874	198.74	10 INT	HF77P	312
21-Sep-04	KR18973	189.73	0.5	HF84P	18
22-Sep-04	KR19015	190.19	10 INT	HF87P	28
22-Sep-04	KR22460	224.6	0.5	HF90P	12
13-Oct-04	KR19645	196.45	0.5	HP01P	17
14-Oct-04	KR19874	198.74	0.5	HP02P	246
14-Oct-04	KR19874	198.74	5	HP03P	42

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